United States
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Agriculture

Agricultural
Research
Service

Research Planning Conference on Biological Control

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ACKNOWLEDGEMENTS

The success of any meeting of the magnitude and complexity of this Research Planning Conference on Biological Control is dependent upon the input from many people. This Conference was no exception and we appreciate the enthusiastic efforts of all the participants.

We are grateful to the leadership of ARS in their recognition of the importance of a planning conference for biological control and their support of the multidiscipline nature of this Conference. Our thanks go also to Mrs. Delores Haley for her efforts in organizing the Conference and making the Conference a pleasant experience for the participants. In addition, her and Jeanne Hagan's extensive efforts to meet the secretarial needs of the Conference and the resulting report are very much appreciated.

Dr. R. B. Taylorson, Dr. J. J. Drea, and Dr. G. C. Papavizas generated the background data in support of the Conference, suggested participants, and assisted in organizing the Conference. Their efforts are especially appreciated. Also, the assistance of Mr. J. R. Coulson and other staff of the Beneficial Insects Introduction Laboratory in developing this report was invaluable to the success of the Conference.

We are especially grateful to the Group Discussion Leaders for their devotion to the development of thorough and concise reports and to Mr. James Kelleher of AgCanada and scientists from the State agricultural experiment stations and other agencies who gave generously of their time to participate in the Conference.

The National Program Staff
Biological Control Team:

R. D. Jackson, Chairman
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INTRODUCTION

More than 20,000 species of agricultural pests, including weeds, nematodes, insects, and plant pathogens, cause losses amounting to $12 billion annually in the U.S. The discovery, importation, and utilization of biological control agents are important tools in managment of these pests, particularly in view of the current worldwide concerns for food supplies and the quality of the environment. The use of natural enemies to control pests represents an effective means of increasing production efficiency; thus, contributing directly to the stability of the agricultural economy while reducing adverse impacts upon the environment. Furthermore, the cost-benefit ratio of natural enemy importation programs is very favorable.

In view of benefits from biological control of agricultural pests, the Agricultural Research Service (ARS), in cooperation with other public agencies and private organizations, must continuously evaluate the opportunities to develop the use of biological agents to control pest insects, weeds, nematodes, and plant pathogens.

The information developed during this Conference provides guidance to the Agricultural Research Service to assure that its research programs on biological control are effective and targeted to solve the most important pest problems amenable to biological control approaches. The report will be used by ARS program leaders and scientists as a basis for program decisions to assure the achievement of this goal.

THOMAS J. ARMY
Deputy Administrator
National Program Staff

The successful use of biological control agents to suppress or control pest insects and disease vectors, weeds, plant pathogens or nematodes, is a reality! These biological agents, provided by nature, are safe, effective, and minimize environmental hazards often associated with the use of broad spectrum pesticides. The workshop report contains succinct statements of pest problems, the state-of-the-art technology, listing of specific target pests, and candidate biological control agents, as well as recommendations of various research strategies and approaches to attain ARS biological control research objectives. In synopsis, it is an effort to "translate the directions and targets of the ARS program plans into the most important and promising specific research needs and problems to be pursued" (E. B. Knipling, Introductory Statement, March 20, 1984). Following is a summary of the high priority pest problems amenable to biological control and research needs to fill information and technology gaps and future research thrusts employing the concepts and uses of biological agents to control or suppress target pest insects, weeds, plant pathogens, and nematodes.

INSECTS: Nature has provided safe and effective beneficial insect parasites, predators, and disease-inducing microbes that suppress insect pests. Scientists at the ARS laboratories, in turn, are selecting the most promising of these naturally occurring agents and researching how they might be better used to protect man, his food, fiber, and shelter. One example of the kinds of successes ARS scientists have had is the control of the cereal leaf beetle, a major pest of wheat and other small grains, with a beneficial parasitic wasp introduced from Europe. Another example is the development of safe, effective commercial products, based upon beneficial disease-inducing viruses, fungi, protozoans, and bacteria to control or suppress major insect pests (i.e., bollworm/budworm complex, gypsy moth, grasshoppers, citrus mites, and caterpillar pests of vegetable and row crops). The workshop report recommends specific research to expedite these successes and provide the necessary foundation for future success on use of beneficial parasites, predators, and pathogens to control insect pests.

Insects, ticks, and mites also cause considerable livestock loss and human suffering primarily through biting, irritation, and the spread of diseases. Biocontrol research must be intensified to develop alternative methods to chemical control and as a component of integrated systems for pest management. Insect pests most amenable to biocontrol technology and of the highest priority include the stable fly/house fly/filth fly complex, mosquitoes, horn flies, face flies, black flies, cockroaches, and the imported fire ant. Foreign exploration for potential pathogens, parasites, predators, and competitors should be a major thrust common to all these insect pests. Another major research thrust is genetic engineering of pathogens and parasites to adapt them to specific habitats, environmental conditions, and host species. In preparation for this thrust, basic research is necesary on detailed studies of biocontrol agent life cycles. As new biocontrol agents are discovered or engineered, a greater research effort must be made to improve propagation technology and new strategies devised to incorporate biocontrol agents into integrated systems to economically manage pest populations. Results of this research will provide cost-beneficial techniques for control with minimal environmental hazards and without complications of insecticide resistance.

WEEDS: Significant advances in biological control of weeds are expected in the near future. An example is the development of mycoherbicides for controlling specific weeds in cropland situations. Following the success achieved with Colletotrichum on control of northern jointvetch in rice and soybeans, new microbial agents are being developed in Arkansas and Mississippi. Two new agents, an Alternaria and a Fusarium, have been patented and commercially licensed. The Alternaria attacks sicklepod, showy crotalaria, and coffee senna. The Fusarium is active against velvetleaf, prickly sida, and spurred anoda. Encouraging results have been obtained in Florida and California in the control of the aquatic weed, waterhyacinth, by several insects and in the use of hybrid lines of herbivorus fish to control a broad range of aquatic weeds. In rangeland weeds, seedhead-, stem-, and root-boring insects are in advanced testing or in the early release stages for the control of diffuse and spotted knapweed and yellow starthistle.

PLANT PATHOGENS: Very promising lines of research are underway on using biological agents to control soilborne, aerial, and postharvest diseases of plants. As example, several biocontrol fungi have been discovered that effectively reduce soilborne diseases of vegetables. Some of these have been patented and mass-produced by industry. Research at Oxford, North Carolina, and Beltsville, Maryland, has demonstrated that aerial leafspot diseases of tobacco, peaches, and peanuts may be reduced in half utilizing biocontrol fungi. The brown rot disease of stored stone fruits has been experimentally controlled using a biocontrol bacterium. Biocontrol of postharvest diseases may be especially promising since the storage environment can be more easily maintained. It is only a matter of time before biocontrol will be another alternative approach, along with the traditional uses of chemicals, resistance and cultural practices, for controlling diseases of plants.

NEMATODES: Natually occurring biocontrol nematode agents already control pests. Among the most widespread and damaging are the cyst and root knot nematodes. Repeated cropping of cyst nematode-infested soils in parts of Mississippi, with highly susceptible varieties, results in unexplainable losses of these nematodes. Scientists have isolated microorganisms such as fungi and bacteria from these nematodes and demonstrated, in the laboratory, that they, in turn, can destroy the nematode.

CONFERENCE OBJECTIVES

The Research Planning Conference was convened to evaluate opportunities to increase agricultural production efficiency, preserve the environment, and conserve natural resources through the use of biological agents to control pest insects, weeds, nematodes, and plant pathogens; and to provide guidance to the Agricultural Research Service in conducting an effective biological control research program.

Specific activities were to:

1. Identify pest problems that were amenable to biological control approaches.

2. Establish biological control research priorities for diseases, insects, nematodes, and weeds.

3. Develop background documentation on high priority target pests.

4. Identify gaps in present biological control technology and provide recommendations to strengthen those program areas.

5. Develop recommendations to integrate new technologies into biological control research.

LIST OF ATTENDEES

Acock, B.
Adams, P.
Aldrich, R. J.
Alvey, M.
Andalaro, J. T.
Anderson, L. W.
Anderson, R.
Andres, L.
Arbogast, R. T.
Ashley, T. R.
Ayers, W.

Bouse, L. F.
Bovey, R. W.
Bram, R.
Brodie, B. B.
Bruckart, W. L.
Buckingham, G.

Center, T.
Civerolo, E.
Connick, Jr., W.
Coulson, J. R.
Cunningham, G.

Dame, D.
Day, W. H.
DeLoach, J.
Dogger, J. R.
Dorschner, K.
Dougherty, E. M.
Dowler, W.
Drea, J. J.
Duke, J.
Dulmage, H.
Dysart, R. J.

Endo, B.

Fassuliotis, G.
Faust, R.
Fisher, T.
Fravel, D.
Fuester, R. W.

Gassner, G.
Geisler, E.
Goodpasture, C.
Graham, H. M.
Greenstone, M.

Haile, D.
Harris, R. L.
Henry, J.
Hopper, K. R.
Howell, C. R.
Hoy, M.
Huettel, R.
Humber, R.
Hung, A.

Ignoffo, C.

Jackson, R.
Jones, W.

Kelleher, J. W.
King, E. G.
Knipling, E. F.
Knudsen, G. R.
Kopacz, B. M.

Labeda, D.
Lewis, L.
Lewis, J. A.
Lewis, W. J.
Linscott, D. L.
Lopez, J.
Lumsden, R. D.
Lyon, R.

Marois, J.
Marsh, P.
Martin, P.
McGaughey, W. H.
Metterhouse, B.
Meyerdirk, D.
Miller, R.
Millhollon, R.
Moline, H.
Moorehead, G.

Nelson, M.
Nickle, W.
Norland, J.

Ouye, M. T.
Owens, R.

Papavizas, G.
Patterson, R.
Perdue, R.
Perkins, D.
Powell, J.
Puttler, B.

Quimby, P. C.

Ragsdale, D.
Rebois, R.
Reichelderfer, K.
Ridgway, R.
Ristaino, J.
Rodriguez-Kabana, R.
Rosenthal, S.
Rossman, A.

Sailer, R. I.
Sasser, J.
Sayre, R.
Schroder, R.
Schweizer, E. E.
Seawright, J. A.
Shaw, W.
Sheih, T. R.
Shapiro, M.
Soper, R.
Spurr, H. W.
Sutter, G. R.

Taylorson, R.

Undeen, A.

Vail, P.
Vakili, N
Vaughn, J.

Waterworth, H.
Wells, J. M.
Wilson, C.
Witz, J. A.

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Drea, J. J.
Powell, J.
Puttler, B.

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Buckingham, G.

Andres, L.
Bovey, R. W.
Dorschner, K.

3. Plant pathogens to control weed pests

Bruckart, W. L.

Millhollon, R. W.

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Lopez, J.

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Hopper, K.
Lewis, L.
Sutter, G. R.
Witz, J. A.

2. Biological agents to control plant pathogens

Marois, J.

Acock, B.
Rodriguez-Kabana, R.

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Bouse, L. F.
Moorehead, G.
Patterson, R.
Ridgway, R.

2. Fungi to control weeds and plant pathogens

Connick, Jr., W.

Alvey, Mark
Lewis, J. A.
Labeda, David

D. Increasing Effectiveness through Manipulation and Habitat Management

1. Insects to control insect pests

Harris, R. L.

Greenstone, M.
Lewis, W. J.
Meyerdirk, D.
Ragsdale, D.
Schroder, R.

2. Insects to control weeds

Center, T.

Linscott, D. L.
Schweizer, E. E.

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Brodie, B. B.

Sayre, R.

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Ristaino, J.

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Dowler, W.

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Hung, A.
Miller, R.

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Dulmage, H.

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F. Gentic Manipulation and Engineering

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   Gassner, G.

   Hoy, M.
   Knipling, E. F.
   Seawright, J. A.

2. Eukaryotes to control insects, plant pathogens, nematodes, and weeds

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   Fassuliotis, G.
   Huettel, R.
   Papavizas, G.
   Vakili, N.

3. Prokaryotes to control insects, plant pathogens, nematodes, and weeds

   Faust, R.

   Ignoffo, C.
   Martin, P.
   Owens, R.
   Waterworth, H.

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Kelleher, J.
Perkins, D.

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DeLoach, J.

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Taylorson, R. B.

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Rebois, R.
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Bram, R. A.
Coulson, J. R.
Kopacz, B. M.
McGaughey, W. H.
Nelson, M.
Undeen, A.

J. Taxonomic Research on Fungi in Support of Biological Control

Rossman, A.

Endo, B.
Humber, R.
Marsh, P.

K. Heterogenicity in weed populations in relation to biological control

Duke, J.

Perdue, Robert
Rosenthal, S.

Discussion Group A.1

Chairman: Richard Dysart

Team Members: John Drea, Janine Powell and Ben Puttler

1. Title:

Research to Identify and Measure Biological Prerequisites in Quarantine: Research in support of quarantine activity involving arthropods to control arthropods.

2. Problem Description and Importance:

The introduction of beneficial organisms from foreign areas is well recognized as an essential component of biological control research, however, the introduction of exotic organisms presents potential hazards which must be resolved and/or minimized. Until its identity and primary habit are confirmed, the introduced organism and associated material must be contained in a quarantine facility. Great potential for damage exists in the inadvertent introduction of either a pest serving as host for a beneficial organism or of a secondary parasite. Once in quarantine, quick accurate identifications are essential. Also, suitable hosts and food for hosts must be available. Proper conditions must be provided for mating and oviposition and nutritional requirements must be sufficiently satisfied to permit normal development. Special conditions may have to be met to deal with developmental phenomena such as diapause. Ultimately, vigorous and healthy organisms must be produced in sufficient quantity to survive shipment and to serve as colonizing stock for permanent establishment in the field.

3. Status of Science and Technology:

The technology for containment has advanced to the point where introduced organisms can be held with assurance that they will not escape. Environmental control technology has also advanced to permit precise control of conditions for holding and rearing. However, there is a need for new and better means of sustaining individuals and colonies of the beneficial organisms. Are there more alternate hosts or synthetic hosts on/in which oviposition or development can take place? There is a need for more knowledge on specific conditions to insure mating, oviposition, and longevity. There is also a need for better techniques to maintain the organisms in an inactive state until sufficient numbers can be accumulated or a suitable time is reached for shipment or liberation.

Developments in data processing and computer technology have provided means of documenting the collection and release of organisms, but there is still a need for improved programs and systems for the exchange and retrieval of such information among quarantine facilities.

4. Objectives:

   a. To improve the ability to maintain and increase beneficial insects in quarantine.

   b. To more explicitly identify and characterize species and biotypes of the beneficial insects.

   c. To improve criteria for "clearing" beneficials for release from quarantine.

   d. To improve methods of shipment and storage, in order to retain the viability and vigor of the biotic agents.

   e. To provide improved capability for retrieval of all pertinent information concerning identifications, foreign collections, incoming and outgoing shipments, field releases, and voucher specimens.

5. Recommended Approaches in ARS:

   a. Develop improved methods for obtaining successful mating and oviposition for specific taxonomic groups of natural enemies.

   b. Develop improved artificial diets for both host insects and their natural enemies including the use of surrogate hosts.

   c. Determine methods of inducing and terminating diapause.

   d. Develop techniques to distinguish between closely related species and biotypes, using electrophoretic and other advanced methods.

   e. Develop acceptable protocols to ensure that organisms released are not harmful to the environment.

   f. Develop new designs for shipping containers; improved methods to stabilize conditions while beneficials are in transit.

   g. Develop methods for improving the exchange of information on the identity, importation, and release of introduced beneficials with use of computer technology.

6. Resource Needs:

   a. Expertise in classical biological control, quarantine procedures, taxonomy, physiology and behavior, biochemistry, population genetics, and computer technology.

   b. There is a need to upgrade equipment in existing quarantine facilities, especially with regard to bioclimatic cabinets and ADP hardware.

7. Selected References:

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Brown, V. K. and Hodek, I. (eds.). 1983. Diapause and life cycle strategies in insects. Dr. W. Junk Publ., The Hague.

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Fisher, T. W. and Finney, G. L. 1964. Insectary facilities and equipment. pp. 381-401 in P. DeBach (ed.), Biological Control of Insect Pests and Weeds. Chapman & Hall, London.

Leppla, N. C. and Ashley, T. R. (eds.). 1978. Facilities for insect research and production. U.S. Dept. Agric. Tech. Bull. 1576.

van den Bosch, R. and Messenger, P. S. 1973. Biological Control. In text Educ. Publ., New York. 180 pp.

Discussion Group A.2

Chairman: Gary Buckingham

Team Members: Lloyd Andres, Rodney Bovey, and Ken Dorschner

1. Title:

Research to Identify and Measure Biological Prerequisites in Quarantine: Insects to control weed pests

2. Problem Description and Importance:

Over one-half of the major weeds in the United States are species that have been introduced from other countries, existing here free of the natural enemies that help to hold them in check in their native areas. One element of the biological control approach is to search for these natural enemies and to study them in their native areas and/or in domestic quarantine facilities to determine whether their use for weed control in North America is appropriate. Prior to the clearance and lawful release of the organisms in North America we must address the following questions: 1) Whether the organisms will attack the U.S. weedy biotype, 2) whether the host-range of the organism is sufficiently restricted to avoid injury to plants of recognized economic or ecological importance, 3) whether the organism has the potential to significantly stress the weed, and 4) whether the organism has been properly identified and is free of its own natural enemies (Andres and Kok, 1981). Although we strive to carry out as much of the work as possible overseas each candidate must pass through the quarantine facility. The quarantine must be designed and equipped to provide meaningful behavioral data with a minimum of artifact induced problems.

3. Status of Science and Technology:

a. Research in domestic quarantine facilities with insects for weed control depends upon a successful foreign program for supply of the insect candidates. ARS laboratories in Rome, Italy, and Hurlingham, Argentina test and supply many of the insects, but insects from other areas of the world must be obtained through foreign exploration trips or from cooperating foreign scientists. Unfortunately, lack of time and/or of expertise often limit or preclude prequarantine studies. Increased demands on foreign laboratories, reduced support for foreign exploration, and political and bureaucratic problems when dealing with foreign cooperators add to this problem and limit the types and numbers of organisms available to the quarantines. Three ARS quarantine facilities have biocontrol of weed programs: Albany, CA - principally exotic range weeds; Temple, TX - principally native range weeds; Stoneville, MS - principally crop and aquatic weeds. Additional state or university quarantine facilities where weed control research with insects is or has been conducted are Riverside, CA; Blacksburg, VA; and Gainesville, FL (Klingman and Coulson, 1982). There is also

an ARS aquatic weed program at the Gainesville facility and a planned state quarantine facility in Bozeman, Montana. Researchers at the quarantine laboratories are loosely coordinated through various Regional Research Projects and through personal contacts but there is no formal national coordination.

b. Quarantine research with exotic insects for weed control has been conducted in the U.S. for almost forty years beginning with the Klamathweed project. The designs of the present facilities and research methods are the result of modifications and improvement throughout the years based upon the experiences of many researchers. The fact that during the forty year period no insects have escaped and established from U.S. quarantine and none of the insect species released from quarantine for biological control have become pests confirms that these facilities and methods are valid. The rigorous tests conducted in quarantine prevented the release of at least three insect species. Although these tests may have prevented potential pests in those three cases, it is also possible that they may have prevented the release of succesful control agents. Improved techniques are needed to assess not only the potential risk but also the potential benefit of an insect candidate.

4. Objectives:

a. Determine the host range of the biological control candidates assuring that the genetic variability of the organism and of the test plants have been adequately assayed.

b. Ascertain how the candidate organisms stress their host plant (i.e., plant parts attacked, timing of damage) to predict their potential to stress the weed plant in the problem area.

c. Manipulate the natural enemies in such a manner as to free them of their own parasites and pathogens but still maintain their genetic quality.

5. Recommended Approaches in ARS:

Insect host plant recognition and acceptance is governed by a variety of environmental and plant factors. Ideally the insect candidate will be highly host specific and pose little or no threat to plants of recognized economic or ecological importance. Tests for host specificity are best conducted in open areas and natural habitats free of artifacts that might influence host acceptance or lead to the misinterpretation of the tests. However when these tests cannot be conducted in the native area, appropriately designed and equipped quarantine facilities will be needed.

In some instances in the past the insect candidates have actually been too host specific and after release have not been able to establish on the U.S. weeds. To avoid this problem, yet select candidates with high specificity and potential control value, the following approaches need to be applied:

a. Use appropriate genetic technique (i.e., DNA fragmentation gel electrophoresis) to ascertain the genetic variability of the U.S. weed and compare this with populations of the plant obtained from its native range.

b. Use appropriate genetic techniques to determine the genetic variability of the insect candidates and match them to their appropriate host plant biotypes.

c. Develop reliable and practical statistical methods to (1) assure that sufficient individuals of a population have been tested to portray its true host range and selection behavior and, (2) to assure that sufficient individuals of a test plant species have been tested.

d. Develop criteria for compiling and standardizing test plant lists so that the appropriate plants are tested by all researchers.

e. Develop fundamental knowledge on the biochemistry of insect-host plant interactions as an aid to establishing the causal basis of host plant selection.

f. Develop fundamental knowledge of the biology and behavior of each candidate organism in order that the appropriate stages are included in the specificity tests.

g. Develop quality control techniques applicable to the small scale rearing of weed control candidates in quarantine to assure the availability of quality insects for test purposes and release.

h. Document how the insect candidates stress their host plants - the tissues destroyed, the timing of the attack - in order to ascertain their ability to stress and control the weeds.

i. Develop fundamental knowledge about the pathogens and parasites associated with plant feeding insects in order to facilitate their elimination from insect colonies destined for testing and release.

6. Resource Needs:

a. Expertise in plant taxonomy, insect taxonomy, population genetics of insects and weeds, plant physiology, insect rearing, entomology, and weed science.

b. Present quarantine facilities are adequate for our current insect weed control programs, however, an increase in the number of programs and of target weeds will put a strain on facilities in some regions.

7. Selected References:

Allen, G. E. 1981. Impact of diseases on insects and procedures for detecting and eliminating them from cultures prior to release for biological control. Proc. V. Int. Symp. Biol. Contr. Weeds, Brisbane, Australia, 1980:221-232.

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Mackauer, M. 1981. Some aspects of quality and quality control of biological control agents during insectary propagation. Proc. V. Int. Symp. Biol. Contr. Weeds, Brisbane, Australia, 1980:207-220.

Myers, J. H. and M. D. Sabath. 1981. Genetic and phenotypic variability, genetic variance, and the success of establishment of insect introductions for the biological control of weeds. Proc. V. Int. Symp. Biol. Contr. Weeds, Brisbane, Australia, 1980:91-102.

Discussion Group A.3

Chairman: William Bruckart

Team Member: Rex Millhollon

1. Title:

Research to Identify and Measure Biological Prerequisites in Quarantine: Plant pathogens for biological control of weeds.

2. Problem Description and Importance:

Most of the weedy plant species in the United States are introduced, many without an adequate complement of natural enemies to maintain plant densities at manageable levels. Furthermore, many weed species are not adequately controlled by conventional cultural and chemical weed control methods. Biological control by introducing or manipulating natural enemies has been shown effective in weed management. Plant pathogens of weeds comprise a major group among the natural enemies under consideration and have been used successfully in weed control, both in cultivated crops (augmentative approach, mycoherbicides) and in rangeland, pastures, and waste places (classical approach).

Most weed pathogens for use in the classical sense are of foreign origin and are collected in geographic areas of the world where the weed species is native. These pathogens are evaluated for use in biocontrol in a quarantine facility located at the Plant Disease Research Laboratory (PDRL) in Frederick, MD, since there are no USDA-ARS plant pathologists stationed overseas.

Evaluation of exotic plant pathogens in quarantine is required by law to insure against unintentional or accidental release of exotic plant pathogens and is the second step in the introduction process. Only weeds of recognized importance are targets of research with plant pathogens.

Research is conducted to learn: 1) if the pathogen is safe to use (i.e. does not attack important North American native and crop plants), and 2) if the pathogen is capable of causing sufficient stress to the target species to warrant its use.

Effective evaluation of weed pathogens in quarantine is limited by 1) the number of pathogens received from foreign sources, 2) the difficulty in interpreting certain plant reactions in the greenhouse and laboratory, 3) the difficulty in obtaining propagative material to include in host range studies (particularly of native, threatened, and endangered plant species), and 4) the limitations in the quarantine operation (space and personnel).

3. Status of Science and Technology:

Scientists involved in weed biocontrol in the U.S.A. submit proposals to the Working Group on Biological Control of Weeds which include a list of plants for host range study based upon published voluntary guidelines and generally accepted procedures. Data are collected by the scientist(s) to fulfill prerequisites and used in support of an additional proposal for introduction and release of promising biocontrol agents. Evaluation of plant pathogens utilizes basic greenhouse propagation techniques and standard isolation and inoculation procedures from plant pathology.

Plant pathogens for evaluation in biological weed control are obtained from three sources: 1) cooperating entomologists located at the Biological Control of Weeds Lab in Rome, Italy; 2) foreign plant pathologists hired under cooperative agreement; and 3) state and federal scientists from the U.S.A. on brief (2-6 week) collecting trips.

Successful introduction of *Puccinia chondrillina* for the control of rush skeletonweed (*Chondrilla juncea*) resulted from collecting the pathogen in Italy, evaluating it at PDRL, and releasing it in the northwestern U.S. with cooperation of federal and state agencies. This process required approximately 4 years to complete. Currently, pathogens are being evaluated for use in the control of leafy spurge (*Euphorbia esula-virgata*), musk thistle (*Carduus nutans*) and yellow starthistle (*Centaurea solstitialis*).

The only ARS facility for plant pathogen quarantine and containment is located at PDRL in Frederick, MD. The only other plant pathogen quarantine facility in the U.S.A. is located at the University of Florida in Gainesville. Research at that facility is directed primarily toward control of aquatic weeds in that state.

4. Objectives:

Receive plant pathogens from foreign sources; identify, and evaluate their potential in biological control of weeds.

a. Determine specificity and virulence of candidate pathogens by inoculating:

   1. Collections of the target weed species from several locations in the world.

   2. Plant species closely related to the target species.

   3. Economically important North American plant species, especially those related to the target species.

   4. Native, endangered or threatened North American plant species, especially those related to the target species.

b. Characterize the nature of the disease on the target (and non-target) plant species.

c. Maintain purity and pathogenicity of potential biocontrol agents.

d. Utilize current biotechnology to accomplish objectives stated above.

5. Recommended Approaches in ARS:

The effectiveness of introducing exotic plant pathogens for weed biocontrol requires strong support from foreign sources to observe and study weed diseases in the field, and to provide pathogens for evaluation.

a. Emphasize and coordinate foreign exploration for plant pathogens to generate additional plant pathogens for evaluation in containment.

b. Develop fundamental knowledge of the taxonomy (to subspecies and biotype) and ecology of the target weeds in the U.S. and relate this knowledge to the plant in its native range.

c. Expedite evaluation of plant pathogens and other natural enemies by either 1) identification of germplasm (e.g. cultivars, species) and seed sources for use in host range studies, or 2) establishment of a germplasm bank (particularly for endangered or threatened plant species and for economically important plant species, such as designated corn, wheat, and soybean varieties).

d. Develop predictive approaches to weed biological control by integrating data on plant taxonomy, plant ecology and plant disease.

6. Resource Needs:

a. Two or more additional plant pathologists, at least one to study and collect pathogens overseas, and one to receive and evaluate pathogens in the U.S.

b. Expand quarantine facilities for the evaluation of plant pathogens in the U.S., either at Frederick or at other locations in the U.S.

c. Identify germplasm and sources of germplasm, or a system for maintenance of a germplasm collection.

d. Expertise in taxonomy of plant pathogens in support of evaluations in quarantine.

e. Expertise in modern approaches to plant taxonomy to identify biotypes of weeds in the U.S. and match these with plants overseas. This would possibly facilitate establishment of compatible host-parasite combinations in the U.S.

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Discussion Group B.1

Chairman: Juan Lopez

Team Members: Danel Haile, Keith Hopper, Les Lewis, Gerry Sutter, and Jack Witz

1. Title:

New Modeling Approaches: Application of modeling and systems analysis to use of insects and pathogens for biological control of weeds and insect pests.

2. Problem Description and Importance:

The use of insects and pathogens for the biological control of weed and insect pest populations has been shown to constitute an environmentally compatible and economically viable approach. Because this approach is by its nature, very selective in its effects on pest populations, there is no widespread disruption of the ecosystem and ecosystem complexity is maintained. The spatial scale of decision-making for many biological control techniques is often greater than that for other methods, thus adding to the complexity.

Because of the complexity and the interactions with other control strategies, a systems approach is needed. Modeling and systems analysis techniques are available to deal with ecosystem complexity, but are often not being applied in biological control research. Application of these techniques would be of value in evaluating biological control approaches as well as in the planning of research. Many data have been collected; however, many of these data have not been incorporated into mathematical models. Furthermore, current modeling efforts often do not encompass the full range of mathematical techniques available.

The systems approach and modeling are powerful research tools that apply to most, if not all, biological control research considered by the workshop. The objectives and approaches developed herein, must, therefore, be considered in conjunction with each of the other research areas developed and must not be considered as separate research topics.

3. Status of Science and Technology:

The "systems approach" offers a highly structured format within which complex problems are considered, needs identified, alternative solutions evaluated, and final programs implemented. It has provided biologists, along with other disciplines, the ability to consider and evaluate complex relationships associated with ecological problems. Mathematical modeling, a component of the systems approach, has been used successfully to guide and link biological experimentation, thus helping scientists develop a more comprehensive understanding of the system of interest and its operation.

At present, the status of systems analysis and modeling of biological control of insect pests and weeds varies widely with different research problems. For some ecosystems and pests, no modeling at all has been attempted; for others, complex simulation models of the pest-natural enemy interaction have been developed. For no systems are highly precise, predictive models of natural enemy dynamics available. However, a number of past and on-going pest management modeling efforts shed light on the strengths and pitfalls of modeling and systems analysis of biological control. Some of these efforts with insect pests include: Brown et al. (Mississippi State University), Hartstack et al. (ARS, College Station), and Stinner et al. (North Carolina State University) - *Heliothis* spp.; Croft et al. (Michigan State University) - fruit pests, Gutierrez et al. (University of California) - cotton pests, Haynes et al. (Michigan State University) - cereal leaf beetle; Shoemaker et al. (Cornell University) - alfalfa weevil; and Weidhaas et al. (ARS, Gainesville) - houseflies. The systems approach has just begun to effect the orientation of epizootiological research. Recent work on the population biology of *Entomophtora muscae* in the onion agroecosystem (Carruthers, Michigan State University) has shown the utility of using these methods to guide and synthesize research findings in the use of pathogens for the control of insects.

Very little has been done on the modeling of natural enemy/pest dynamics for classical biological control, either in evaluation of potential candidates or assessing reasons for success or failure.

Three crucial areas needing modeling effort are the dispersal of pests and natural enemies, the stochasticity of their population dynamics, and the interaction of biological control with other strategies. Also, application of optimal control theory to simplified versions of complex simulation models has been used in a few systems and may prove productive.

4. Research Objectives:

a. Develop systems science capabilities to aid in the planning, implementation, analysis, and synthesis of biological control research:

   1. Analyze existing data bases using systems approach including, but not limited to, computer modeling.

   2. Develop a research approach which uses systems analysis to aid in directing new and on-going biological control research.

   3. Construct computer software packages which allow personnel unfamiliar with computer techniques to use computerized data bases and execute biological models associated with pest/natural enemy systems.

b. Incorporate pest/natural enemy modeling into ecosystem level analysis for pest management systems:

1. Evaluate the effects of ecosystem level stimuli on population dynamics of pests and natural enemies.

2. Model biotic agents as a component within pest management decision-making models for weeds and insect pests.

c. Investigate a broad range of techniques for modeling biological control systems, e.g., dynamic programming, probabilistic modeling, and models incorporating spatial distribution.

5. Recommended Approaches in ARS:

It is imperative that modeling and systems analysis be utilized by scientists for a more efficient use of biotic agents in pest suppression. To facilitate this, the following approaches should be undertaken:

a. Provide support for systems analysis and quantitative modeling activities in biological control programs by improving existing efforts and by initiating new efforts in high priority biological control research areas where modeling activity does not currently exist. Support should include scientific personnel trained in modeling and systems analysis techniques; technical support for modeling such as programmers, where needed; and adequate computing equipment.

b. Educate existing "non-modeler" scientists on the importance and benefits of quantitative modeling as applied to biological control research programs. This too includes minimum skills necessary for such scientists to converse and work productively with modelers.

6. Resource Needs:

a. Dedicated computer equipment with sufficient capability to support high priority biological control modeling and systems analysis research.

b. Scientists trained in development and application of models and systems analysis.

c. Workshops to train multidisciplinary research teams in development and use of systems analysis and modeling.

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Discussion Group B.2

Chairman: James Marios

Team Members: Basil Acock and Rodrigo Rodriguez-Kabana

1. Title:

New Modelling Approaches: Computer models for the development of biological control systems for plant pathogens.

2. Problem Description and Importance:

The use of biological control (biocontrol) agents for plant pathogens is a practical method of recent development. The success or failure of biocontrol efforts depends on an accurate understanding of the interactions of the biocontrol agent and the target organism. The factors that affect these interactions are many and complex, e.g., climate, biotypes, pathosystem, etc. The lack of understanding of these factors often leads to erratic and disappointing results. These types of complex systems are most suitable for computer models. The development of theoretical computer models of pathogen-biocontrol systems would indicate which disease epidemics are most suitable for management of the disease through the use of biocontrol agents and provide information as to which attributes the control agent must have. The computer models will identify gaps in our knowledge of pathosystems and biocontrol systems. A prerequisite for development of the model will be to acquire an accurate description of the population and growth dynamics of each of the organisms in the system.

3. Status of Science and Technology:

Recent developments of computer technology have led to ready availability of user-friendly, large-capacity, fast, inexpensive, and reliable computer systems. This technology has made possible widespread use and acceptance of complex statistical analyses in biological sciences. The potential of computer technology to contribute to our understanding of complex interactions of host, pathogen, and control agents has not yet been realized.

There already exists several crop growth models which are sufficiently mechanistic to interface with models of pathosystems including biocontrol agents. Current model development activities are typically concerned with single crops or pathogens and only rarely are attempts at interfacing these individual models made. Models considering biocontrol agents have not been developed.

A major impediment to the development of a theoretical model to describe biocontrol systems is the lack of appropriate population dynamics information. The data are usually limited in scope and too few controlling variables are measured or even considered. For this important scientific tool to be realized, appropriate data must be

obtained. Techniques and concepts are available for the acquisition of this information. Disciplinal insularity is a major obstacle to the development of these proposed objectives. Interdisciplinary cooperation is essential to successful development of computer models for the study of biocontrol systems.

4. Objectives:

a. Develop a computer simulation model that can be used to investigate the dynamics of the interactions of the host, pathogen, and control agent to facilitate the selection of those diseases which are amenable to biological control practices. The model will indicate which stages of the epidemic are most suitable for control measures and identify the necessary attributes of the control agent. This model would be a simple, empirical, and as far as possible, generalized model which would require as inputs the parameters of the population dynamics equations.

b. Define and study the variables pertaining to the population growth dynamics of the pathogen and control agent such that the data are interactive with developed plant growth models. This will include appropriate epidemiological studies.

c. Data from population growth dynamic studies will be used to develop mechanistic models of selected pathosystems. The models will quantify those attributes of the control agent necessary for effective disease control.

5. Recommended Approaches in ARS:

a. Identify contributors and arrange workshops to develop the simple empirical model described in objective "a."

b. Refine general model using several pathosystems.

c. Define specific parameters and variables of major economic diseases and use the general model from objective "a" to test the feasibility of biological control systems.

d. Acquire data for spatial, temporal, and innate considerations of the population dynamics of the host, pathogen, and control agent. Assemble data into mechanistic model of objective c.

e. Develop cooperative studies with biological control specialists to validate models and implement effective biological control measures.

6. Resource Needs:

a. The objectives require the cooperation of a multidisciplinary nature. The disciplines required are: plant physiology, biometrics, plant pathology, microbial ecology, epidemiology, mycology, agronomy, plant genetics.

b. Equipment needed includes adequate computer facilities, data acquisition devices, controlled environment chambers, field plots, electronic weather monitoring stations.

c. A clearing house for exchange of electronic and hard copy information as well as organization of annual workshops.

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Discussion Group C.1

Chairman: Edgar King

Team Members: Thomas Ashley, L. Fred Bouse, Gary Moorehead, Richard Patterson, and Richard Ridgway

1. Title:

Technology for Propagation and Release (Augmentation): Arthropods to control arthropod and weed pests

2. Problem Description and Importance:

Natural enemies (predators, parasites, and phytophagous arthropods attacking weeds) often do not occur in adequate numbers to maintain insect and weed pests below the economic or tolerance threshold. New natural enemies may be introduced (classical biological control), but this approach has not solved many of the major pest problems in the USA. This is particularly true in relatively unstable ecosystems where the pest (host or prey) may be separated from its natural enemy in space or time. Separation may be caused by establishment of exotic pests in absence of natural enemies; animal husbandry or cultivation practices that cause widespread destruction of the natural enemies' food, shelter, and oviposition sites; and use of pesticides that adversely affect natural enemy and competitor populations as well as induce through selection processes, resistant pest populations. The growth of susceptible crops over large areas that are devoid of other plant species or grouping of livestock allows for rapid colonization and buildup of insect pests and uninhibited growth of certain plants (weeds) because they are not being regulated by their enemies or competitors. Moreover, interactions (including the normal lag time of the natural enemy population behind the pest population) between codeveloping host or prey and natural enemy populations may limit the ability of self perpetuating natural enemy populations to maintain pest populations below acceptable thresholds. Numbers of natural enemies may be augmented by various means, but emphasis here is on direct increase of the natural enemy through propagation and release.

3. Status of Science and Technology:

The technical feasibility of propagating and releasing predators and parasites to control pest arthropods has been widely demonstrated in greenhouses, fruit and citrus orchards, forage and row crops, and in control of muscoid flies and mosquitoes. However, commercial usage of this approach to pest control in the USA is greatly limited by economic feasibility and social acceptability. Conceptually, weed feeding arthopods should also be equally effective when augmented, but successful examples of technical feasibility in this area are few.

Failure to correctly identify species of augmentatively released natural enemies has often resulted in their ineffective use. A striking example is the culture and release of a species identified as *Trichogramma minutum* Riley on Barbados for sugarcane borer control only to discover after 20 years of releases that the species was *T. fasciatum* (Perkins). The taxonomy of North American species in this genus has been clarified, but the need to conduct other comprehensive biosystematic studies to ensure selection of the most suitable species or strain for each specific augmentative use is now well recognized.

Present propagation methods for predators and parasites are largely restricted to rearing them on live hosts (often unnatural) in field or laboratory insectaries. Up to 22 species of parasites can now be reared *in vitro*, but mass production on artificial diet is not yet operationally feasible. Large scale commercial application of the augmentative approach in the USA may depend on development of suitable diets and methods for mass producing and storing high quality natural enemies. ARS engineers have played a vital role in the development of mass rearing procedures and release technology for many insect species including the screwworm, *Heliothis* spp., medfly, pink bollworm, and gypsy moth. Unfortunately, most of these individuals have either retired and not been replaced or reassigned to other research activities. Engineering input will be required for development of cost-effective natural enemy mass rearing and release programs.

Sex pheromones have been identified for many insect pest species and can be used in traps to detect pest presence. Numbers of insects caught in these traps along with weather data can be used in models to predict pest occurrence and duration of occurrence several weeks in advance. Knowledge of the time of occurrence, duration of occurrence, and pest density is essential for timing releases of the natural enemy as well as determining the number required for release to achieve the desired level of control.

In order to develop rational augmentation programs, the relation between numbers of natural enemies released and their impact on the pest population and the commodity protected must be assessed. Dynamic simulation modeling based on an understanding of the population processes underlying these interactions will be required for these assessments. Data are being accumulated that will aid in understanding dispersal attributes, however, it is inadequate for most species. These data are necessary to determine the optimal size of the release area. Retention of the natural enemy in the target area and its uniform distribution and consistent performance may be dependent on our ability to simulate host density and preferred habitat through the application of behavioral chemicals.

Implementation of augmentative procedures will depend on successful demonstration of economic feasibility, but conflicts with other pest control and crop production practices may still limit operational feasibility and acceptance of the procedure. Thus, integrated systems will have to be developed that complement the augmentative approach.

4. Research Objectives:

a. Identify the natural enemy complex for selected pests within systems that optimize the use of biological control by augmentation.

* b. Develop and improve efficient mass production of high quality natural enemies.

c. Develop and improve technology for storage, shipment and release of natural enemies.

* d. Improve understanding of the interrelationship (biology and ecology) between the host or prey and natural enemy.

e. Develop improved sampling and predictive capability to guide in the augmentation of natural enemies.

* f. To determine the optimal size of the release area based on the movement and dispersal attributes of the pest and natural enemy as well as spatial heterogeneity of the production system.

g. Develop integrated systems that complement the augmentative approach.

h. Assess the technical and economic feasibility of the augmentative approach.

i. Develop implementation procedures for transfer of augmentative release technology.

* Signifies area of major importance in limiting feasibility of the augmentative approaches.

5. Recommended Approaches in ARS:

Experimental approaches below are listed in sequential order assuming a model crop, pest, natural enemy, and production system. More or less knowledge of attributes in each of these areas will govern where research should be initiated. Interdisciplinary research will be necessary for successful development of the augmentative approach regardless of the production system and pest selected.

a. Select the most effective species or strain of natural enemy for release for each specific augmentative use including those improved through breeding techniques and/or gene transfer.

* b. Establish the nutritional requirements for selected natural enemies and develop artificial diets and *in vitro* rearing procedures where appropriate.

c. Develop measurable quality control criteria for mass production of natural enemies.

d. Develop automated mass production systems including engineering specifications for efficient, safe production of high quality natural enemies.

e. Define environmental parameters and develop engineering specifications for storage, shipment, and release of natural enemies.

* f. Investigate the mechanisms governing the dynamic interactions between the pest and natural enemies.

g. Develop sampling and predictive technology to judge when to release the natural enemy, how many to release, and duration and frequency of the releases.

* h. Measure movement and dispersal of the pest and natural enemy as affected by mate finding, host or prey searching, and weather.

i. Develop technology for use of host finding substances and other factors influencing performance of augmented natural enemies.

j. Evaluate, develop, and integrate pest control and other production practices that are not detrimental to the augmented natural enemy.

k. Develop quantitative information on the impact of the release of the natural enemy on the pest populations and product to assess benefits (economic feasibility and social acceptance).

* Signifies area of major importance in limiting feasibility of the augmentative approach

6. Resource Needs:

a. Three areas of research are major obstacles in advancement of the augmentative approach. (1) The first is assessing nutritional requirements and development of <u>in vitro</u> rearing procedures for parasites. Inability to efficiently mass rear natural enemies of a consistently high quality will continually limit the approach to a few specialized situations. <u>We recommend formation of 2 to 3 interdisciplinary teams each consisting of an insect physiologist, biochemist, and nutritionist whose assignment is to focus on one or more important natural enemies that have been demonstrated to have potential in the augmentative approach</u>. (2) Movement and dispersal of the pest and natural enemy have continually plagued researchers attempting to design, conduct, and evaluate experiments on the augmentative approach. Minimal size of the release area is often questionable and movement of the natural enemy from the release area may limit its effectiveness. <u>We recommend resolution of this area size prior to funding tests for the augmentation concept, and this resolution will require cooperation between the engineer and population ecologist</u>. (3) Modeling each system will serve as a guide toward developing an understanding of these complex interactions. <u>We recommend cooperation between a fundamental insect biologist, insect behaviorist, and insect population ecologist within each system to achieve this goal</u>.

b. Other resources include engineers to develop specifications for automating, rearing, storage, shipment, and release procedures; pathologists to limit diseases and microbial contamination within the rearing environment; insect behaviorists to assess and ensure product quality; and economists to assess economic feasibility and social acceptability of the propagation and augmentation program.

7. Selected References:

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Discussion Group C.2

Chairman: William Connick, Jr.

Team Members: Mark Alvey, Jack Lewis, and David Labeda

1. Title:

Fungi to Control Weeds and Plant Pathogens

2. Problem Description and Importance:

It is now widely recognized that biological control of plant pathogens and weeds is a distinct probability for the future and can be successfully exploited in modern agriculture. Two major approaches which may be followed to enhance biological control are: (1) changing the microbial environment, or (2) direct introduction and application of biological control preparations. The latter approach, which is of biotechnological importance, is more feasible and acceptable to agriculture than manipulation of the environment. However, despite the attractiveness of this approach, little basic knowledge has been acquired concerning growth, formulations, storage, and delivery of biocontrol agents compatible with current agricultural practices and industrial applications. In order to achieve maximum biological control with the effective fungi at our disposal, we must obtain information on fundamental concepts concerned with: (1) effective propagules for biocontrol, (2) influence of food base and fermentation factors on biomass and propagule production, (3) type of formulation and influence of formulation ingredients (i.e., carriers, diluents, or adjuvants) on preparation effectiveness, (4) effect of storage conditions on shelf life, (5) proliferation, survival, and establishment of the biocontrol agent, (6) timing and placement of applications, and (7) compatibility of soil and foliar environment and the interactions with biocides (chemical and biological) on preparations. The knowledge currently existing for production and delivery of microbial insecticides should be exploited and adapted for production of microbial fungicides and herbicides.

3. Status of Science and Technology:

a. The use of fungi to control weeds and plant pathogens is in an early experimental stage. There are currently two registered mycoherbicides, Colletotrichum gloeosporioides f. sp. Aeschynomene for northern jointvetch, and Phytophthora palmivora for milkweed (strangler) vine in citrus. A rapidly growing number of potential mycoherbicides is currently being evaluated. One fungal control has been developed for plant pathogens (Peniophora gigantea against Fomes rot of trees), and there is a bacterium (Agrobacterium radiobacter) in commercial use to control crown gall of rosaceous species.

b. After finding a promising biocontrol agent, two of the most fundamental considerations for development of the antagonist are: (1) production, and (2) formulation of a viable, effective material using both available and innovative biotechnology. For biomass production of fungal antagonists, current technology employs deep tank and solid substrate fermentation using agricultural products that are readily available in unlimited quantities. The ability to produce in submerged fermentation will be critical for the development and commercialization of biocontrol fungi. Subsequent formulation of the biomass to contain a viable, stable preparation is one of the most difficult challenges in biocontrol product development. Commercially available formulations of microbial agents include wettable powders and emulsifiable and flowable liquids.

c. Recent progress has indicated the possibility of using species of the genera Alternaria, Septoria, Colletotrichum, Fusarium, Protomyces, and Cephalosporium for the control of weeds. Although little disease control has been shown with fungi, Athelia has reduced apple scab in the field and Sporidesmium has reduced Sclerotinia diseases.

4. Objectives:

a. Determine inexpensive, easily-available substrates (molasses, corn steep liquor, sulfite waste liquor, whey, Brewer's yeast, nitrogenous tankage, etc.) which give the greatest biomass of the most effective propagule (mycelia, conidia, ascospores, chlamydospores) during fermentation in the shortest period of time. Establish the best methods for production of biocontrol agents with deep-tank and solid fermentation techniques utilizing optimal substrate concentration, pH, aeration, and temperature.

b. Formulate fungal biocontrol agents using existing and innovative technology to best demonstrate small-plot efficacy. In this regard, study the effect of carriers and adjuvants on the effectiveness of the biocontrol fungus to control weeds or plant diseases.

c. Cooperate with SAES, other universities, and industry to develop economical, effective, and acceptable biocontrol preparations using existing and innovative biotechnology based on fundamental knowledge derived from research.

5. Recommended Approaches in ARS:

a. ARS must be committed to biocontrol concepts, biocontrol technology, and mechanisms of biocontrol activity as basic research areas for long-term experimentation which are high risk but can give high returns.

b. For successful implementation of this thrust, various cooperative efforts among disciplines must be established within and among ARS laboratories (soil and weed scientists, plant pathologists, fermentation and formulation chemists, etc.).

c. ARS should establish a formulation research group to assist the ARS researchers in determining formulation requirements for biological control agents and in providing formulations for initial and early experimental evaluation.

d. ARS should support research on development of integrated weed and crop disease management systems that include fungal biocontrol agents as components.

e. ARS should support research to find, identify, and characterize potential microbial biocontrol agents and improve fungus strains.

f. ARS should be active in organizing and promoting educational programs with extension, SAES, other universities, and growers with regard to the ecological and cost/benefit advantages of biological control programs.

g. ARS should cooperate closely with industry to determine, clarify, and resolve problems of common interest concerning both basic and applied research.

6. Resource Needs:

a. Expertise in fermentation and formulation chemistry, plant pathology, weed science, soil microbiology, and adequate support personnel.

b. Required facilities for production and evaluation of the fungal biocontrol agents and their formulations.

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Discussion Group D.1

Chairman: Robert L. Harris

Team Members: Matthew Greenstone, W. Joe Lewis, Dale Meyerderk, David Ragsdale, and Robert Schroder

1. Title:

Increasing Effectiveness through Manipulation and Habitat Management: Entomophagous arthropods to control arthropod pests

2. Problem Description and Importance:

Entomophagous arthropods are key components of most biological control programs. Research has continued to demonstrate that the effectiveness of these biological control agents is highly dependent upon habitat variables. Identification of these variables and the mechanisms whereby they influence the behavior of entomophages is essential to the achievement of consistent effective performance in biological control programs. Specifically, this basic information will enable us to develop habitat manipulation technologies, such as modification of cropping schemes and cultural practices, and provision of supplementary nutritional sources, foraging stimuli, and other essential resources, in order to enhance the effectiveness of native and introduced entomophages. Acceptance of these technologies will require their proper integration with other components of the overall agricultural production systems.

3. Status of Science and Technology:

There is a substantial and long-standing body of empirical and experimental evidence that the structural and floristic diversity of habitats influence entomophage diversity, abundance, and performance. Nevertheless, variation in entomophage performance due to habitat factors has generally not been given due consideration in the design and execution of biological control programs.

Over the past several decades it has been established that more diversified habitats, such as those provided by weedy borders, hedgerows, and polycultural planting schemes, tend to have more abundant and diverse entomophage faunas than simpler habitats. We know that such increased diversity provides alternate food resources, shelter and microclimatic buffering, and facilitates more efficient searching behavior. However, the behavioral mechanisms involved in these influences are not sufficiently understood to rationalize the development of manipulation technologies from this basic information. Recent research has demonstrated that the density and distribution of host or prey individuals influences the colonization, retention, and efficacy of search of entomophages. Optimal densities and distribution have been simulated by supplementary applications of hosts or prey individuals or host or prey substances to the habitat, but to date only on an experimental scale.

Our ability to evaluate the impact of habitat manipulations on natural enemy effectiveness is hampered by the lack of adequate techniques for quantitating and partitioning pest mortality due to parasitism, predation, and disruption, e.g., heavy Spodoptera larval mortality due to dispersal induced by disturbance from spider activity versus that due to spider predation. Our knowledge of the interaction of species-specific predation and parasitism rates with mortality from other sources is weak. Ultimately, the activity of entomophages must be translated into overall impact on pest population densities and crop yields.

The effectiveness of entomophages is strongly influenced by various practices, such as timing, frequency and intensity of tillage, irrigation procedures, weed and plant disease control practices, and selectivity, timing, and mode of application of pesticides. Effective utilization of habitat manipulation technologies will necessitate harmonious integration with agricultural production practices.

4. Objectives:

a. Understand characteristics of the habitat that influence the effectiveness of entomophagous arthropods. Major areas within this objective will include: physical, chemical and biological attributes of the habitat; impact of habitat features on host/prey location behavior and agricultural production practices on entomophage effectiveness.

b. Develop manipulation techniques and strategies to enhance the effectiveness of entomophagous arthropods.

c. Obtain data in the proper form for development of models pertinent to manipulation and habital management.

d. Integrate manipulation technologies into existing pest management and agricultural production systems.

5. Recommended Approaches in ARS:

The habitat provides the entomophagous arthropods with food, shelter, feeding sites, and information to guide them in locating their host or prey. An understanding of these factors and their roles in the total biology of entomophagous arthropods will provide for the development of technology to maximize their effectiveness. The following experimental approaches should be applied:

a. Determine the importance of the following aspects of habitat features on performance of entomophagous arthropods: vegetation structural and species diversity; availability of alternate hosts/prey, nutritional sources, and shelters and microclimatic conditions.

b. Determine the mediating sensory cues and mechanisms governing the habitat-finding and within habitat host/prey-location behaviors of entomophagous arthropods.

c. Determine factors within the habitat that influence interspecific interactions including predation, parasitism, interference, and other forms of competition.

d. Determine habitat features and other biological characteristics vital to the effective performance of candidate exotic entomophagous arthropods at the time of exploration. Determining habitat features is vital in the case of endangered habitats such as tropical rain forest.

e. Develop improved technologies to measure the performance of entomophagous arthropods and the influence of habitat manipulation on that performance.

f. Determine the influence of present agricultural production practices on the effectiveness of entomophagous arthropods, develop improved agricultural production practices to optimize their performance, and integrate these into existing systems.

g. Determine the role of soil characteristics and soil management practices on the effectiveness of entomophagous arthropods.

h. Determine habitat characteristics important for effective overwintering of entomophagous arthropods, and develop technologies to enhance their overwintering and survival at other critical times in their life cycles.

6. Resource Needs:

Expertise in plant and arthropod taxonomy, ecology, natural product chemistry, entomology, botany, silviculture, biochemistry, behavior, agricultural engineering, weeds, modeling, animal science, and plant breeding.

7. Selected References:

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Discussion Group D.2

Chairman: Ted Center

Team Members: Dean Linscott and Edward Schweizer

1. Title:

Increasing Effectiveness of Biological Control of Weeds with Insects through Manipulation and Habitat Management: Insects to control weeds.

2. Problem Description and Importance:

Insects show more potential for biological control of weeds than is currently realized due to lack of knowledge of how combined weed management approaches interact to reduce or enhance the effect of herbivores. Also, the subtle, chronic long-term effects which frequently result from biological control may be mistaken for ineffectiveness. Very little information is available in the literature on chronic effects of herbivory on various facets of weed life cycles. These data are needed to determine how to augment effects of herbivory with plant growth regulators, herbicides, environmental stresses, other herbivores, plant pathogens, cultural practices, and other means. Implementation of integrated control requires that insect/weed interfaces be fully understood and involves full knowledge of biology of the weed, biology of the insect, and interactions between the weed and the insect. Determination of influence of stresses will enable identification of those which cause weeds to be more susceptible to herbivore damage. The goal is to discover stress that is "selective" in the sense that it affects the weed but not the insect. Determination of insect response to the stressed weed must follow. This information can identify environmental components which are amenable to manipulation and which are or can be stress factors. In addition, it may be possible to develop means whereby an increased affinity of the insect for the plant is attained by altering the plant chemistry to reduce/increase secondary metabolic products, tissue nutrients, attractants, feeding stimulants, or plant hormones. Finally, by developing predictive systems models, new manipulative technology can be transferred to weed management specialists.

3. Status of Science and Technology:

Insect/plant interactions represent a very large complex field of science which, in the past, has been largely ignored but is now significantly increasing. Much general information is becoming available but little is applicable to insect/weed systems for management purposes. Some work has been done on various aspects of increasing fertility levels (particularly nitrogen levels) to enhance insect feeding. This has worked well in Australia for control of the floating weed Salvinia molesta. Some preliminary attempts have been made to integrate growth retardants with biological control. In principle, a growth retardant could be used to reduce the growth potential of a weed

and thereby allow biological control agents to more effectively keep it under control. Many studies have been carried out to discover synergistic effects of mixtures of biological control agents, especially insects with other insects or insects with pathogens. Little has been done with environmental manipulation as a source of stress and as a means of augmenting insect effect.

Recent evidence indicates that some herbicides may interrupt biochemical processes in plants resulting in build-up of intermediate compounds in metabolic pathways. Chemicals interrupt these processes at various points and produce different by-products. If these intermediate by-products increase affinity of the plant to insects, then a very powerful management tool would be available. This possibility results from the recent advent of new types of herbicides; however, no research has been done to determine its potential for integration with biological control. Other aspects of phytochemistry/herbivore interaction have been examined from agronomic and ecological points of view but very little from a weed control perspective.

4. Research Objectives:

a. Understand how target weeds respond to biological, chemical, cultural, environmental, and mechanical stresses.

b. Learn means of manipulating stress factors to increase affinity and efficacy of insects as biological control agents.

c. Develop methodologies and strategies aimed at manipulating stress factors to enhance, augment, and optimize the use of biological control.

d. Transfer knowledge and technology necessary for field application and widespread implementation of biological control practices that utilize insects.

5. Recommended Approaches in ARS:

The key to increasing effectiveness of insects for control of weeds through manipulation and habitat management lies in the factors which influence the insect/plant interface. These factors are varied in nature and involve several biologically oriented disciplines. The following experimental approaches need to be taken:

a. Determine and identify chemicals which can alter plant development and metabolism so as to enhance efficiency of insects through positive changes in life history parameters (e.g., growth rates, fecundity, survivorship, etc.).

b. Investigate biotic factors which potentially interact with insect biocontrol agents, such as plant pathogens, beneficial plants (allelopathy), other insects, nematodes, etc.

c. Develop fundamental knowledge of the relationship(s) between plant nutrient availability and host plant quality and the effects these interactions have on the affinity of insects to weeds.

d. Develop fundamental knowledge of how water management (irrigation practices, drawdowns, etc.) affects host plant quality and subsequent management of target weeds.

e. Identify mechanical, tillage, grazing, harvesting, and other cultural practices which can enhance effects of insects on target weeds.

f. Develop and validate models to identify stress responses of target weeds using well-characterized insect/weed systems.

6. Resource Needs:

a. Expertise in general areas of entomology, weed science, plant physiology-biochemistry, aquatic biology, agronomy, statistics, and mathematical modeling.

b. Scientists, support personnel, and operating capability for overall development of the approaches.

c. Due to the complex nature of biological control systems, committments must be made for long-term, in-depth research.

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Discussion Group D.3

Chairman: Bill Brodie

Team Member: Richard Sayre

1. Title:

Fungi to Control Nematodes: Increasing effectiveness through manipulation and habitat management.

2. Problem Description and Importance:

Although over 200 species of fungi are known to attack numerous plant-parasitic nematodes, none have been developed for commercial use as biorational nematicides. Information on the basic biology and population dynamics of only a few of these nematophagous fungi in soil is available. No major research effort is being made currently to manipulate or manage the soil environment to determine the factors that favor these potential biocontrol agents over their plant nematode hosts. Recently, several major constraints have been placed on the management of nematode populations in soil. In general, we have not addressed fully the following problems in our research programs: (1) the efforts of no or reduced tillage on nematode population dynamics; (2) the loss or restricted use nematicides of major nematicides; and (3) the effects of programs initiated to stop soil erosion such as the use of legume cover crops on nematode population dynamics. There are still other problems, many of which have developed as the result of economic change, the practice of monoculture of crops, constraints imposed by regulatory agencies, and in general, the increased demand for a more efficient agriculture system for a growing population and dwindling agricultural work force.

3. Status of Science and Technology:

a. The promise of biological control of nematodes began with an early observation (1937) that decomposing plant material substantially reduced the incidence of root-knot nematode disease. Two theories were suggested to explain the observation. Decomposition products released in soils were directly toxic to nematodes, and second, the added food base stimulated populations of several microorganisms that were antagonistic or parasitic to nematodes. Both of the theories have been substantiated, as several metabolic products released by certain soil bacteria and fungi are toxic to nematodes and over 300 different species of soil microorganisms have been found to parasitize or prey upon nematodes. Both toxic decomposition products and the numerous antagonists of nematodes are clear evidence that biological control of nematodes occurs naturally.

b. Much, if not all, of the impetus for the growth of the science of nematology stems from the economic losses caused by plant nematodes and the subsequent response of governments and private industry to create and support departments and agencies that combat those losses. Only a few nematode species are readily seen (e.g., cyst and root-knot species) and most are microscopic and virtually all are hidden in soils or roots, but the losses attributed to nematodes are easily demonstrated by using nematicides that increase crop yield (e.g., dichloropropene- dichloropropane, DD and 1,2-dibromo-e-chloropropane, (DBPC). Consequently, the use of nematicides is the major method of control. Other methods of control are resistant crop varieties and cultural practices which include crop rotation, flooding, deep-plowing, fallowing, and trap crops. Each of these reduces the dependence on chemical control. Each method has been successfully demonstrated under certain environmental conditions and is in use to some extent. Additional research could greatly increase their use and enhance their value. Currently, no biological control methods for nematodes are available to commercial growers. However, research observations suggest that biological control methods for nematodes could be readily developed and possibly incorporated into integrated pest management systems.

4. Objectives:

a. Identify, select, and preserve promising fungal biocontrol agents of plant nematodes for later manipulation in soils.

b. Develop and register selected fungal isolates as effective biological control agents for major and minor crops.

c. Incorporate the biological control tactics into integrated systems compatible with or complementary to the control of other crop pests.

5. Recommended Approaches in ARS:

Manipulation and habitat management is one of the many approaches to increasing effectiveness of biocontrol agents. However, in the final analysis, the habitat in which biocontrol agents must function will determine the success or failure of the organism. Basic research task in this area encompasses broad disciplines in the fields of mycology, zoology, and soil microbiology as well as nematology. The following experimental approaches are needed:

a. Develop fundamental knowledge of the microhabitat of nematodes.

b. Use methods from the field of soil microbiology to manipulate the environment of microbes to enhance growth and development.

c. Develop fundamental knowledge of the life cycles of model biocontrol agents and the biotic and abiotic factors affecting this cycle.

d. Develop fundamental knowledge of stages of target nematodes that are most susceptible to parasitic activity.

e. Develop techniques of synchronizing infective stages of the parasite with susceptible stages of the host.

f. Develop fundamental knowledge of factors affecting susceptibility of nematodes to parasitic or predatory action of other organisms.

g. Develop techniques for *in vitro* culture of potentially successful biocontrol agents.

6. Resource Needs:

Expertise in nematology, mycology, ecology, and soil microbiology, 4 SY's.

7. Selected References:

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Discussion Group D.4

Chairman: Peter Adams

Team Members: Debbie Fravel, Chester Howell, and Jean Ristaino

1. Title:

Increasing Effectiveness through Manipulation and Habitat Management: Biological agents to control soilborne plant pathogens.

2. Problem Description and Importance:

A major impetus to the development of biological control has been the adverse impact of toxic chemicals in the environment. There is a need to explore alternative control measures, especially where conventional methods are inadequate. The use of beneficial microorganisms, especially fungi and bacteria, to control plant diseases caused by soilborne fungi holds great promise for the future of production agriculture. Without these organisms, organized agriculture as we know it today would probably be impossible because plant diseases would reduce yields of all monocultured crops to near zero. Agricultural situations are known in which certain soils are suppressive to specific diseases caused by soilborne pathogens. Research is in progress to try to learn how and why these soils are suppressive to diseases. A number of soilborne fungi are known to be parasitic on the survival structures of certain soilborne plant pathogens. Some of these mycoparasites have been evaluated as potential biocontrol agents with some success. Other soilborne fungi and bacteria are thought to suppress plant pathogens in soil by the production of inhibitory substances which are detrimental to the plant pathogen. Presumably these beneficial microorganisms could be developed into practical biocontrol agents. With one or two exceptions, little is known about the environmental factors which affect the activity of these beneficial fungi and bacteria and their interactions with pathogens in soil. Research on the ecology of soilborne pathogens and their natural biological control agents will change these beneficial organisms into practical biocontrol agents resulting in increased yields of agricultural crops.

3. Status of Science and Technology:

The use of beneficial microorganisms to control plant diseases is not a new idea. However, field studies over the last few years are now suggesting that this idea can become a practical reality. Some of these beneficial organisms such as *Trichoderma*, *Talaromyces*, and *Gliocladium* species have been studied for a long time and have recently been shown to control specific diseases under agricultural production systems, but their mechanisms of action are not well understood. Other beneficials such as *Coniothyrium minitans* and *Sporidesmium sclerotivorum* have been shown to reduce disease incidence or severity in the field and their mechanisms of action and ecological requirements are known. A great deal of research is needed to further elucidate the mechanisms of action of potential biocontrol agents and to learn their ecological

requirements so that they may be used in an efficient and effective manner to control diseases caused by soilborne pathogens. To develop effective agents we must learn how to grow the agents in quantity, how and in what quantity to apply them to the field, how to manage the agents in the field, and how frequently they must be applied to obtain acceptable disease control. To be successful, fundamental research on the survival and ecology of both the target plant pathogen and biocontrol agent will have to be undertaken. This research includes studies on the population dynamics of both organisms in soil. This information is required so that methods may be developed to alter the ecology of the soil ecosystem to the benefit of the biocontrol agent and/or to the detriment of the plant pathogen.

Objectives:

a. Acquire fundamental information on the ecology and survival of propagules of target soilborne plant pathogens and the etiology of the diseases they cause so as to obtain information on how and where to apply a potential biocontrol agent.

b. Acquire fundamental information on the ecological parameters which affect survival and activity of potential biocontrol agents applied to soil. The population dynamics of the plant pathogen and the agent in soil should also be investigated. This information will dictate how the biocontrol agent must be managed in the field.

c. Determine the mechanism of disease control by potential biocontrol agents. This will aid in development of efficient screen techniques, to determine how and when to apply the agent for successful disease control, and to understand where system breakdown may occur.

d. Determine the nutritional requirements of the biocontrol agent for _in vitro_ growth and sporulation to learn how best to grow the agent in quantity.

e. Investigate the feasibility of the use of multiple agents for disease control.

f. Investigate the integration of biocontrol agents into agricultural production systems, including pesticide compatibility, agent formulation, and cultural practices.

Recommended Approaches in ARS:

Basic research in this area of biological control technology encompasses many disciplines in the biological sciences including; plant pathology, mycology, biochemistry, soil science, ecology, and physiology. Results of this research should provide us with the tools to manipulate agricultural production systems to reduce disease losses. Eventually results obtained in this area will be useful to molecular biologists and genetic engineers who should be able to develop improved strains of biocontrol agents.

a. Develop fundamental knowledge on the ecological parameters affecting survival, population dynamics, and activity of potential biocontrol agents and pathogens in soil so as to learn how to apply and manage the biocontrol agent in the field.

b. Determine the mechanisms of control by specific biocontrol agents in soil and use the information obtained to develop disease control strategies, and to improve screening techniques.

c. Develop techniques to study the activity of plant pathogens and biocontrol agents in their natural habitats.

d. Develop techniques and practical methods to integrate and manage the activities of biocontrol agents in agriculture production systems. These techniques and methods should be derived from basic ecological studies on the plant pathogens and biocontrol agents mentioned above.

e. Cooperate with industry, state and other federal agencies to develop the most efficient method for producing, utilizing, and evaluating the efficacy of potential biocontrol agents and their registration for use by farmers.

f. Investigate the use of multiple agents for the control of either a single or several diseases.

6. Resource Needs:

Expertise and a commitment in the following scientific disciplines is needed: plant pathology, mycology, soil science, soil microbiology, biochemistry, physiology, agronomy and horticulture.

7. Selected References:

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Discussion Group D.5

Chairman: Harvey Spurr

Team Members: Edwin Civerolo, and William Dowler

1. Title:

Increasing Effectiveness Through Manipulation and Habitat Management: Biological control of diseases of aerial plant parts.

2. Problem Description and Importance:

Plant disease losses are 10-13% of potential yield world-wide. The amount of loss to plant disease varies among commodities. For example, the annual loss to disease in peanuts is 28%, whereas, in cotton the loss is 12%. The cost for disease controls may be considered a loss also. The cost for disease control averages 3% of the annual crop loss to disease. Individual control methods vary in cost from the low cost for purchasing disease resistant seed to moderate costs for implementing selected cultural practices to high costs for purchasing and applying pesticides. Biological controls for diseases of aerial plant parts (foliar disease) will be low to moderate in cost depending on the method used to introduce the control. The development of biological control for foliar disease will provide many benefits. A big benefit is the addition of control tactics which will decrease the dependence upon other control tactics and avoid their rapid demise from overuse. The addition of biological control tactics will add flexibility to integrated control strategies and pest management. Thus, the efficiency of crop production is increased. The technology is easily applied to minor crops which have been neglected for many years. Biological control benefits both growers and consumers. The low cost for biological control benefits small and large farmers. Because biological controls are based upon ecological principles, there is reduced hazard to the environment and to anyone who contacts the biological agents. Biological agents such as bacteria are produced from renewable resources decreasing the demand on petroleum resources used to produce chemicals.

3. Status of Science and Technology:

Recent in-depth explorations of foliar microflora and its impact on disease have shown that certain bacterial antagonists can be managed to control foliar disease. Knowledge basic to the biocontrol mechanism, formulation procedures, and application techniques now provide a foliar disease biocontrol strategy. One of the more promising candidates for foliar biocontrol is Bacillus thuringiensis (Bt). This bacterium and other bacterial species were studied under field conditions during several growing seasons. The experiments consistently produced disease control ranging from 30 to 70%. This knowledge, coupled with recent information obtained from laboratory studies, indicates there is good potential for obtaining complete or economically acceptable field control within a few years. Results were from field studies of peanut Cercospora leafspot and tobacco Alternaria leafspot diseases. The

selected bacterial antagonists have a broad spectrum of activity with potential for controlling many fungal pathogens. The potential of Bt for foliar disease biocontrol will be a focal point for research and development activity because this bacterium is available, accepted and utilized for insect biocontrol. Strains of Bt must be selected from interaction studies with fungal pathogens. This selection should be augmented by studies of growth conditions in relation to antagonistic activity using techniques and equipment such as constant flow chemostats. The selected isolates must be evaluated for foliar application by developing specific formulation procedures.

4. Objectives:

a. Isolate, identify and introduce microbial antagonists into aerial plant surfaces and the phylloplane for the biological control of bacterial and fungal pathogens.

b. Develop systems for inducing host resistance to bacterial, fungal and viral pathogens by managing the introduction to the host of microbial agents (or their derivatives).

c. Identify through studies of microbial ecology the physical and biological characteristics of aerial plant surfaces and the phyllosphere pertinent to the management of interactions for biological control of disease and the prevention of frost injury.

5. Recommended Approaches in ARS:

a. Develop standardized bioassays for identifying, improving and monitoring biocontrol agents.

b. Develop fundamental knowledge of the mechanisms by which biocontrol agents and induced host resistance control plant pathogens.

c. Develop improved methods for production, formulation and application of biocontrol agents.

d. Develop improved strains of biocontrol agents by selection, genetic engineering and other techniques.

e. Develop improved bacterial strains for the prevention of frost injury to foliage by selection, genetic engineering and other techniques.

f. Develop model systems for studying aerial plant disease biocontrol with antagonists or induced host resistance.

g. Develop fundamental knowledge of the aerial plant surface and phyllosphere including the identification of physical and biological factors and their interactions.

h. Develop techniques for managing aerial plant surface and phylloplane interactions.

6. Resource Needs:

a. Develop an "Aerial Plant Disease Biological Control Laboratory" with several plant pathologists, a microbial ecologist, a microbiologist and a molecular biologist.

b. Establish a working group for the development and coordination of research, research resources, and support systems for aerial plant disease biological control through a communication system.

7. Selected References:

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Spurr, H. W., Jr. 1981. Experiments on foliar disease control using bacterial antagonists. Pages 369-381 _in_: J. P. Blakeman ed., Microbial ecology of the phylloplane. Academic Press. London.

Discussion Group E.1

Chairman: Reece I. Sailer

Team Members: Akey Hung and Richard Miller

1. Title:

Genetic Manipulation and Engineering - Insects to Control Insects and Weeds: Selection to obtain more effective biotypes of natural enemies: (1) Insects to control insect pests and weeds.

2. Problem Description and Importance:

Insect pests and weeds are adapted to more or less well defined habitats. In order for a natural enemy to be an effective agent for control, it must be able to live in the habitat of its host. Within this habitat it must also be able to find the host and have sufficiently high fecundity to overtake and suppress the host population. It must also be able to synchronize its life cycle to that of the host in order to remain an effective control agent. Since host species normally encompass populations exhibiting a range of adaptability to different environmental conditions within their habitats, it follows that natural enemy species must likewise be composed of populations adapted to the particular habitats of their hosts. Also, host populations may become resistent to attack by previously well adapted enemy populations or escape into a habitat that is inaccessible or unsuited to the enemy species. The variously adapted host populations and those of their corresponding natural enemies are biotypes. Biological control researchers confronted with a pest problem should define the habitat of the pest and learn why associated enemy species fail to provide the required level of control. From this information, the specifications of an effective enemy can be established. With this knowledge, populations of the natural enemy species can be sought and screened for adaptation to the specified habitat. If no preadapted biotype can be found, then through selective breeding or other techniques, effort should be made to develop a population having the required characteristics.

3. Status of Science and Technology:

Basically, the problem of biotypes concerns ability to find, characterize and utilize, genetically determined intraspecific diversity. The required technology is well advanced but unfortunately, application of technology has been limited. In part this can be attributed to availability of resources, but is further complicated in the case of foreign species by problems of logistics as well as administrative and political considerations. There is in addition, urgent need for biosystematic research at both the species and population levels of natural enemy groups on a worldwide basis. Past research, primarily of an emperical nature, has demonstrated the importance of biotypes in bringing about or maintaining successful control of pest species. One such example is control of the walnut aphid in California by an Iranian biotype of Trioxys pallidus following failure of a biotype from southern France. Currently, research is

underway in ARS to obtain more effective control of the imported cabbage worm through introduction of a biotype of Apanteles rubecula from Yugoslavia, an earlier introduction originating in England having failed because of incorrect photoperiod response.

While modern genetic techniques are available to identify and quantify diversity within a population or between populations, much research is needed to relate this diversity to phenotypic traits important for purposes of biological control. Finally, knowledge of the genetic basis of desirable traits is an essential first step toward selection for useful biotypes or for application of recently developed genetic engineering techniques that offer promise of developing biotypes not found among natural populations.

4. Research Objectives:

   a. Foreign exploration to obtain germplasm of natural enemy biotypes as well as of potentially effective species to be imported and maintained in culture for indepth study of genetic diversity and presence of traits useful for biological control.

   b. Museum based biosystematic studies of important natural enemy groups needed to provide knowledge of species relationships and names with which to communicate knowledge about the biology, behavior, genetics and utilization of natural enemy species and biotypes.

   c. Formal genetic studies of natural enemies designed to elucidate inheritance of phenotypic characteristics such as chromosome number, karyotype, sex determination and physiological or behavioral traits.

   d. Research on genetic diversity of insect pest species and corresponding diversity among the species and populations of enemy species needed to find and define biotypes.

   e. Where genetic diversity has been demonstrated, research on how to best select for desired traits and for incorporation of these traits into a useful biotype should be vigorously pursued.

5. Recommended Approaches in ARS:

   a. Maintain and extend acquisition of enemy species and biotypes from foreign countries giving special attention to means of facilitating acquisitions from those countries where travel by American personnel is inhibited or prohibited by political considerations.

   b. Basic to selection of biotypes is an understanding of the species and development of techniques to detect and define intraspecific populations that comprise biotypes. Thus, close collaboration between taxonomists specializing in groups important to biological control and the scientists engaged in research on the genetics and economic exploitation of natural enemy biotypes must be encouraged.

c. Selection experiments should be designed and performed at various ARS laboratories for the purpose of detecting useful natural enemy biotypes.

d. Study the mendelian inheritance of desirable traits of natural enemies and determine the feasibility of incorporation of these into more effective biotypes or genetically modified enemy species.

e. Genetic research should be initiated to establish linkage groups of genetic traits in natural enemy populations.

f. Investigate feasibility of transferring desired traits between species through interspecific hybridization.

g. Investigate techniques for maintaining genetic diversity as well as desired traits in laboratory cultures of natural enemy species and biotypes.

h. Where insufficient natural diversity can be found investigations should be initiated to explore the use of mutagenesis as a means of increasing population diversity and increasing the prospects for obtaining useful biotypes through selection.

i. Selected biotypes should be made available for field tests against target pest species and evaluated at appropriate locations.

6. Resource Needs:

At time of printing not available.

7. Selected References:

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Lucas, A. M. 1969. The effect of population structure on the success of insect introductions. Heredity 24: 151-154.

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Discussion Group E.2

Chairman: Howard Dulmage

Team Members: Ed Dougherty and Martin Shapiro

1. Title:

Selection to Obtain More Effective Biotypes of Natural Enemies: Pathogens to control insect pests.

2. Problem Description and Importance:

We who work on the discovery and development of insect pathogens are not working on an isolated island. Once a useful pathogen has been found, it must be delivered to the insect. This requires a knowledge of the habits of the insect, the development of formulations and application procedures to accomplish this delivery, and close cooperation with industry to evaluate the cost of production and the economic value of the pathogen. However, to conform to the title of this paper, we have restricted ourselves to the selection of a pathogen and have not included in our discussions the effects of formulations or application equipment on the efficacy of a pathogen.

As time goes by, the problem of insect control is not diminishing. The development of insect resistance to chemicals, the ever-increasing restrictions placed on chemicals and environmental pollutants, and the growth of an understanding that pest control should be carried out with minimum effect on the natural populations of beneficial insects has brought about increased concerns for alternatives.

The value of certain naturally-occurring insect pathogens for use in control programs has been recognized for over 150 years, but progress was not made until it was learned how to make this type of biocontrol reproducible. This waited for a scientifically sound approach to be developed. A highly promising start has begun in searching for, and finding, effective agents. At the present time, three isolates of *Bacillus thuringiensis*, two other *Bacilli*, two fungi, and one protozoan are currently registered or in advanced steps of registration in the U.S. In addition, potentially promising bacterial cultures have been found that have differential virulence and/or host range. There are several Baculoviruses, including a granulosis virus, which are close to registration. Also, a cytoplasmic polyhedrosis virus has been registered in Japan; nuclear polyhedrosis viruses are used in the U.S.S.R. Fungi have shown promise as insect control agents, particularly those which belong to the *Mettarrhizium* and *Entomophthora* genera: Foreign registration exists for *Beauveria bassiana* and *Verticillium lecani*. Other forms of microbes may also hold promise for insect control: Chlamydia and Rickettsia agents exist which are capable of disrupting insect life cycles; Spiroplasmas have recently been shown to have insecticidal activity; and several actinomycetes produce insecticidal toxins.

It is important to remember, in assessing the value of these insect pathogens, that the virulences of all the microbial control agents listed are directed only toward insect pests of economic importance and are ecologically compatible with other organisms. The progress to date has shown the rewards that could come from a search for other microbes that could be used for insect control. In the past, microbes used for insect control have been obtained from diseased insects. However, experience in surveying isolates of B. thuringiensis has shown that virulent isolates can be found existing in independence of any insect. Thus we need to search for more effective pathogens, not only from diseased insects, but from other sources as well, including soils, waters, and other natural environments. A promising source of useful isolates are related diseases found in alternate hosts. Although this process has been used to find pathogenic fungi and bacteria, the search should also encompass protozoa, viruses, actinomycetes, and genetic elements.

3. Status of Science and Technology:

Invertebrate pathogens, including the insect pathogens, have not been studied as intensively as vertebrate pathogens. Therefore, the characteristics of the invertebrate pathogens, including taxonomy, biochemistry, physiology, replication, and the mode of action of their pathogenesis, are not understood as well as are the vertebrate pathogens. We need to know more. Also, it has already been shown that different strains of the same bacterial, fungal, or viral pathogen can differ in virulence or spectrum of activity, according to the source of the pathogen: for example, from different geographic locations or different insect hosts. In the case of B. thurinigiensis, it has been shown that different isolates, apparently producing the same toxin, can differ in the quantity of toxin that they produce, an important factor in the economics of these microbes.

In order to be able to select potentially useful microbial insect control agents, adequate diagnostic systems need to be developed. Some of the techniques used in studies of diseases in other animals are adequate for use in studies of insect pathogens, but we need to develop techniques uniquely designed to work with insect pathogens. Currently, the usefulness of a microbial pathogen is judged on the basis of the original isolate, and little effort is put into searches for more virulent and/or efficient strains of the pathogen. Most of the research measuring or increasing the insecticidal activity of these pathogens depends on bioassays, and more efficient and rapid methods of assay are needed. Also, most bioassays have been restricted to measurements of kill and overlook other subtle and/or acute effects such as sterility, growth retardation, etc., all of which could have major impact in assessing the value of a pathogen.

The potential for discovery of new pathogens with new, different, and valuable spectra of activity has been demonstrated in many ways: for example, a screening program on the delta-endotoxins produced by B. thuringiensis has discovered at least 20 different delta-endotoxins with

different activities against a wide variety of insects. This diversity in B. thuringiensis has turned out to be much greater than had been expected or imagined. Thus it had long been thought that these delta-endotoxins were only active against Lepidoptera. We now know that the toxin can be much more diverse in its action than that. This has been most startingly demonstrated by the discovery of B. thuringiensis subsp. israelensis (H-14). This subspecies of B. thuringiensis produces a delta-endotoxin that has no known activity against Lepidoptera, but with very high activity against mosquitoes and aquatic blackflies, completely unexpected targets. Such diversity is not restricted to bacteria: e.g., baculovirus from the alfalfa looper has been shown to possess insecticidal activity against several families of Lepidoptera; moreover, a continuum of genetic relatedness appears when restriction endonuclease digestion patterns of numerous baculovirus genotypic variants are examined.

A coordinated effort to develop the full potential of microbial insect control has not been developed. For one thing, research has not made full use of the many tools available which can assist with current studies, including serological studies, plasmid analyses, HPLC, southern and western blots, protein and nucleic acid analyses, and fermentation studies. The value of these techniques in the development of better microbial agents has already been demonstrated in the research being carried out today, and the use of these, particularly in cooperative programs, should be emphasized in future research.

A diverse and interacting group of talents is needed. However, the exploitation of the potential values that lie in the use of insect pathogens has been restricted to a degree because standardization of assay procedures and coordination of research between laboratories and with field and laboratory entomologists has been solely dependent upon the initiative of individual researchers. Much of this work is best suited to a team effort. Better systems for encouraging and directing communication and cooperation are needed.

4. Objectives:

a. Better means of knowing what pathogens have been found:

1. Improve ability to identify and characterize pathogens.

2. Develop improved screening techniques to detect desirable pathogens.

b. Better means of evaluating insect pathogens:

1. Develop methods of producing and recovering pathogens and determine the effect of these processes on the activity of the pathogen.

2. Develop standardized methods of evaluating pathogens and their effectiveness.

   a. Develop means of quantitatively measuring virulence.

   b. Develop programs to determine the spectra of activity and host range of pathogens discovered in screening programs.

   c. Determine stability and persistence of selected pathogens.

   d. Learn more of the host-pathogen interactions, e.g., on the invasiveness of the pathogen, the host-defenses of the insect, and the transmissibility of the pathogen within the ecosystem.

c. Develop International Screening Programs:

   1. Increase the search for, collection of, and screening of a wide range of microorganisms for useful insecticidal activity.

   2. Determine methods to alter an insect pathogen to enhance its effectiveness or toxicity.

5. Recommended Approaches in ARS:

The development of useful microbial insect control agents will require the use of a wide variety of techniques, including searches for more effective wild types, searches for new types of pathogens, improvement of known pathogens, using such techniques as genetic engineering, plasmid manipulation, classical selection procedures, and the development of improved and more economical methods of producing the agents. To accomplish this without duplication of effort between laboratories, closer communication and cooperation should be developed and instituted between researchers on a regular basis. To achieve these goals, the following experimental approaches should be applied:

a. Develop broadly based cooperative screening programs to discover more potent isolates and to explore their host range and/or spectra of activity.

b. Study the growth and development of the pathogen so as to enable optimization of pathogen yield and activity.

c. Develop standardized _in vivo_ assays under defined laboratory conditions.

d. Develop _in vitro_ assays to quantitate the potency or spectrum of activity of insect pathogens.

e. Explore changes within the host which may reflect activity of the pathogen.

f. Develop serological, biochemical, physical, and genetic technologies to identify, characterize, and authenticate known and newly discovered agents.

g. Explore the use of genetic markers associated with the pathogen which can be correlated with insecticidal activity.

h. Utilize newly discovered pathogens generated by wild type searches in programs designed to enhance their activity through mutagenesis, non-engineered recombinants, in vivo and in vitro passage (through homologous and heterologous hosts) and genetic engineering.

i. Develop techniques for following the stability and persistence of the pathogens either under prescribed laboratory or natural field conditions.

j. Explore the interrelationships between laboratory and field activity and persistence.

k. Develop environmentally tolerant strains of insect pathogens.

6. Resources Needed:

a. Expertise in microbiology, mycology, bacteriology, virology, protozoology, fermentation, insect rearing, microbial genetics, field entomology, insect pathology, insect genetics, microbial taxonomy, immunology, biochemistry of insects, biochemistry of microorganisms.

b. Organization of team efforts and interdisciplinary approaches and procedures for encouraging cooperation and exchange of information between laboratories.

7. Selected References:

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Suggested Chapters:

Chapter 1. Progress in the Microbial Control of Pests, 1970-1980, H. D. Burges, pp. 1-6.

Chapter 11. Insecticidal Activity of Isolates of *Bacillus thuringiensis* and their Potential for Pest Control. Dulmage, H. T. et al., pp. 193-223.

Chapter 15. Genetics and Genetic Manipulation of *Bacillus thuringiensis*. Martin, P. A. W. and Dean, D. H., pp. 299-313.

Chapter 16. Production of Insect Viruses in Cell Culture. Stockdale, H. and Priston, R. A. J., pp. 313-330.

Chapter 18. Control of the Gypsy Moth by a Baculovirus. Lewis, F. B., pp., 363-379.

Chapter 22. Pest Control by Cytoplasmic Polyhedrosis Viruses. Katagiri, K., pp. 433-441.

Chapter 24. Pest Control by the Fungi *Beauveria* and *Mettarrhizium*. Ferron, P., pp. 465-483.

Chapter 25. The Fungus *Verticillium lecanii* as a Microbial Insecticide Against Aphids and Scales. Hall, R. A., pp. 483-499.

Chapter 30. Pest Control by *Nosema locustae*, a Pathogen of Grasshoppers and Crickets. Henry, J. E. and Oma, E. A., pp. 573-587.

Book, "Biological Control in Crop Production: Beltsville Symposa in Agricultural Research," 5, 1980. G. C. Papavizas, Ed., Allanheld, Osmun, Publishers. 1981.

Suggested Chapters:

Chapter 9. Production of Bacteria for Biological Control of Insects. Dulmage, H. T., pp. 129-142.

Chapter 10. Mass Production of Biological Agents for Plant Disease, Weed and Insect Control. Kenney, D. S. and Couch, T. L., pp. 143-150.

Chapter 12. Production, Formulation and Application of Fungi for Insect Control. Soper, R. S. and Ward, M. G., pp. 161-180.

Chapter 14. Nematodes with Potential for Biological Control of Insects and Weeds. Nickle, W. R., pp. 181-200.

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Suggested Chapters:

Chapter 2. *Bacillus thuringiensis* as a Bacterial Insecticide: Basic Considerations and Application. Luthy, P., Cordier, J.-L., and Fischer, H.-M., pp. 35-75.

Chapter 4. Distribution of *Bacillus thuringiensis* in Nature. Dulmage, H. T. and Aizawa, K., pp. 209-239.

Chapter 6. Bacteria for the Control of Arthropod Vectors of Human and Animal Disease. Davidson, E. W., pp. 289-316.

Chapter 9. Control of Insect Pests of Agricultural Importance by Viral Insecticides. Yearian, W. C. and Young, S. Y., pp. 335-386.

Chapter 13. In Vivo Mass Production of Insect Viruses for Use as Pesticides. Shapiro, M., pp. 463-492.

Chapter 16. Persistence of Fungal Insecticides: Influence of Environmental Factors and Present and Future Applications. Weiser, J., pp. 531-558.

Chapter 18. Protozoans for Insect Control. Wilson, G. C., pp. 487-600.

Chapter 21. Regulatory Safety Data Requirements for Registration of Microbial Pesticides. Rogoff, M. H., pp. 645-680.

Discussion Group E. 3

Chairman: Robert Lumsden

Team Members: William Ayers and Charles Wilson

1. Title:

Selection to Obtain More Effective Biotypes of Natural Enemies: Biological agents to control plant pathogens.

2. Problem Description and Importance:

Biological control of plant pathogens is usually based on the availability of specific isolates of antagonistic microorganisms including bacteria, fungi, actinomycetes, and viruses, that are capable of interacting with the crop host-plant pathogen system to prevent or reduce disease. The selection of the biocontrol agent is perhaps the most critical step in the process because it is this factor that determines whether biocontrol is achieved or not. If the biocontrol agent is not effective under natural crop-production or marketing systems it is useless. Also, it may not be the best biotype out of limitless possibilities for achieving effective control. The objective of biocontrol is to obtain the best agent possible to achieve a level of control that is practical and economical. In order to do this we need scientifically based criteria for isolating, identifying, and manipulating organisms to achieve maximum potential. At present we do not have the necessary techniques or data base resources to achieve this except through empirical, cumbersome, time-consuming and often nonproductive means. We need procedures to select biocontrol agents based on scientific knowledge, rapid and efficient bioassay techniques, and analysis of interacting factors through computer technology.

3. Status of Science and Technology:

Selection of biocontrol agents historically has been done by isolating wild-type strains that were discovered by chance encounters, empirical screening, or at best by intelligent selection based on meager available information. Potentially effective biocontrol agents often reduce disease under ill-defined environmental conditions, but in fact, biocontrol is environmentally dependent. These complex ecological systems involve biological, chemical, and physical parameters that determine the degree of success. Biocontrol thus involves multiple factors that may not be ideally in balance in the system where we are attempting to obtain success. Usually, the mechanism of biocontrol is unknown or poorly understood. The lack of knowledge concerning the mechanisms by which biocontrol agents prevent or reduce disease, and under what circumstances, hampers our ability to intelligently select biotypes best suited to perform the intended role in disease control. Tests for biocontrol are often carried out under conditions such as in petri dishes, in sterile soil, or in greenhouses, the results from which often cannot be extrapolated successfully to field, production, or storage systems. It is often difficult to establish the criteria required to adequately assess biocontrol ability. Biocontrol

ideally should be tested in the actual environment where it will be implemented. However, this is often very difficult because of time constraints, space limitations or labor restrictions. Each disease situation is unique in its environmental and biological requirements, therefore, selection is difficult and time-consuming if done empirically. Specialization is usually the case with biocontrol agents, and often involves interactions over a period of time. Broad spectrum screening procedures done historically with chemical pesticides are nonproductive and are ineffective in selecting biocontrol agents. For biocontrol to reach its maximum level of efficiency and effectiveness we require rapid, reliable, and accurate methods for selecting biocontrol agents. Development of these methods will require basic background information on the best sources from which to obtain potential biocontrol agents, an understanding of the mechanism by which they effect biocontrol, and an understanding of the environments in which they best bring about the desired level of disease control.

4. Objectives:

   a. Identify agroecological systems where disease is naturally suppressed; identify the factors in these environments, especially biological factors, that are responsible for the disease suppression; and isolate, identify, and preserve specific biotypes with biocontrol potential.

   b. Develop the data base for systematic selection of biocontrol agents through methodologies that determine the mechanism(s) of action of antagonists, and thus identify specific characteristics of biocontrol that can be utilized in selection procedures.

   c. Develop specific standardized systems of selecting potential biocontrol agents which employ several characteristics that implicate successful biocontrol ability; test with this system potential agents isolated by selective methods from disease suppressive environments and biotypes genetically altered to improve their biocontrol ability; and finally test the selected isolates in standard cultural-management situations where the biological control will be implemented.

5. Recommended Approaches in ARS:

Empirical means and chance encounters have produced few examples of biological control of plant diseases. Although this system is essentially the predominant means to achieve successful biocontrol at present, we need emphasis in ARS to expand basic research and develop a broad data base that can be exploited to systematically and intelligently select specific biotypes of biocontrol agents to be applied for control of individual problem diseases. This approach will require emphasis on the physiology, biochemistry and genetics of biocontrol agents and the ability to decipher the criteria necessary for biocontrol to take place. Data management capabilities and system

modeling will be required to formulate the best criteria for establishing the biocontrol ability of large numbers of naturally occurring biotypes or those genetically manipulated to improve their capabilities.

a. Identify and explore natural disease suppressive situations throughout the world where the chances of selecting the best potential biocontrol agents can be achieved.

b. Define the suppressive environments and identify the biological factors that are responsible for disease control; isolate, identify, and preserve the most promising biocontrol candidates.

c. Determine the specific mechanisms of biocontrol of disease, including antibiosis, mycoparasitism, mycovirus infection, competition, predation, hypovirulence or genetic interference.

d. Develop a data base of information for specific biocontrol systems mechanisms and environmental factors favoring biocontrol. Analyze this information through statistical model systems to determine the most important criteria for success of biocontrol.

e. Utilize these principal criteria to develop selection procedures that are rapid and reliable for identification of biotypes with the greatest potential for success. Biotypes altered by genetic procedures for improved ability to control disease can be selected most effectively by these means.

f. Test the biotypes selected among many potential ones for biocontrol ability in crop production and post harvest systems.

6. Resource Needs:

a. Expertise will be required in plant pathology, microbiology, taxonomy, soil science, microbial and pathological physiology, biometrics and systems analysis.

b. Facilities will be required for physiological and biochemical determination of mechanisms of biocontrol, computer systems, cataloging and dissemination of information, and facilities for collection and preservation of biotypes.

7. Selected References:

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Schneider, R. W. (ed.). 1982. Suppressive soils and plant disease. The American Phytopathological Society, St. Paul, Minnesota.

Spurr, H. W., Jr. 1984. Bioassays - Critical to biocontrol of plant disease. J. Agric. Entomology 1: In press.

Discussion Group F.1

Chairman: George Gassner

Team Members: Marjorie Hoy, Edward F. Knipling, and Jack Seawright

1. Title:

Genetic Manipulation and Engineering: Insects to control insect and weed pests

2. Problem Description and Importance:

Entomophagous species have been collected, colonized, and released in the field to control economic pests, but there is little information on the quality of insects released or specific reasons for their failure to establish themselves or control the host. Also, very little effort has been made to measure the genetic variability of the released or host species in their native habitats, during colonization, after release in the field, or during post-release adaptation.

Genetic strategies and information are needed to develop systems for producing or maintaining arthropods that will be fully effective in the field. Different genetic strategies may be required for augmentative and inundative releases and different genetic strategies may be necessary for different systematic groups of natural enemies. Presently, no gene manipulations and genetic engineering methods are available for use in biological control technology for arthropods. Basic investigations in this area could lead to effective and reliable use of this valuable natural resource.

Opportunities for increasing the efficacy of arthropod enemies of insects and weeds are available through genetic research. Insect gene manipulation and engineering requires both classical and molecular genetic methods. Heritability studies can be used to search for and select strains of biological control agents that are adapted to a particular environment or the adverse effects of pesticides. Biotypes may be identified that show preferences for specific key pests. Selection of insects with superior genetic traits could optimize the use of biological control agents that are permanently established in the environment and improve their effectiveness in biological control programs. Detection methods are required to monitor the quality and behavior of parasites and predators that are likely to undergo undesirable genetic changes when colonized in the laboratory. Application of molecular genetics would provide powerful innovative approaches such as programs that require pesticide resistance or sensitivity and genetic sexing procedures for single sex release. Through a better understanding of biological agents, biological control success rate can be increased. Greater knowledge of the genetics of the pest species and the biological control agents being released can lead to a dramatic breakthrough in the efficacy of these control agents.

3. Status of Science and Technology:

Genetic manipulation and engineering of arthropod natural enemies is in its infancy. Artificial selection of arthropod natural enemies for resistance to pesticides has been achieved with phytoseiid predator mites, and these improved predator strains have been documented to be effective in the field; the strains have established in orchards and vineyards. A pesticide-resistant strain of the green lacewing was also recently developed, but has not yet been field tested.

The potential value of heterosis to improve inoculative release success or to provide standard strains of natural enemies for augmentative purposes has not been assessed. However, based on breeding research with other animals, these techniques may prove beneficial to biocontrol programs. The molecular biology and genetics developed (and being developed) for *Drosophila* offers great promise for developing fundamental advances in genetic knowledge in arthropod natural enemies, and for improving their effectiveness. However, we must develop fundamental knowledge on which genes are desirable, how to isolate them, how to incorporate them into other strains or species, and how these genes are expressed in the new host.

Before genetic improvement can be achieved; however, we must be able to identify biological and ecological attributes critical to the establishment and/or field efficacy of that natural enemy. Another limitation is the fact that, to date, genetic engineers cannot work with quantitative characters; the number of useful attributes known to be determined by single genes in arthropod natural enemies is currently limited. Thus, qualitative characters such as pesticide resistance appear to be most amenable to genetic engineering or artificial selection, but future advances in the field may occur that cannot be predicted now if behavior genetics advances are made.

Fundamental to any genetic selection, hybridization, or genetic engineering project is the ability to rear arthropod natural enemies of high quality for their intended purpose. Thus, maintaining quality is crucial to improving arthropod natual enemies. At present, we know almost nothing about the fundamental genetics (cytogenetics, populations genetics, etc.) of natural enemies, and proposed genetic solutions have not been tested. Colonization today is largely an empirical process. Advances in rearing will require major efforts to understand genetic (and behavioral) changes that occur during colonization; without this knowledge, genetic improvements will be difficult to achieve.

New techniques in germplasm preservation offer opportunities for preservation of desirable biotypes and genetic strains which are difficult and expensive to maintain. This technology should be adapted to diverse natural enemy species.

4. Objectives:

a. Maintain and improve the quality of natural enemies of weeds and arthropod pests of crops during laboratory rearing, including attributes as overwintering, dispersal, survival, and biological control capabilities. This includes defining the specific needs for individual projects.

b. Determine the inheritance of various traits and the structural arrangement of genes of arthropod biological control agents as a basis for future work on biotechnological and other breeding programs.

c. Determine the biological and behavioral characteristics of biotypes of specific arthropod species used in biological control.

5. Recommended Approaches in ARS:

Full development and implementation of genetic technology will depend on a multidisciplinary approach in the research conducted to produce superior biocontrol agents for insects and weeds. Basic research is required across broad areas in order to gain an initiative in the evaluation, breeding, and synthesis of biocontrol agents. The following scientific activities are suggested:

a. Expand and develop basic knowledge of classical genetics and cytogenetics of selected, key biocontrol agents for pest insects and weeds.

b. Select key representative species for population genetic studies aimed at biotype identification, biosystematics, and maintenance of the desired level of genetic variability during the mass production of insects used as biocontrol agents. It is especially desirable to determine the applicability of the vast genetic literature that is available on *Drosophila*.

c. Develop insecticide resistance in biocontrol agents through the use of classical selection methods.

d. Establish teams to conduct genetic engineering research with emphasis on screening for transposable elements, cloning of desirable genes (e.g., insecticide resistance) and gene transfer technology aimed at incorporating desirable genes into biocontrol agents.

e. Expand research on the technology for germplasm preservation.

f. Support training programs for scientists to improve their expertise in the application of genetic methodologies to biocontrol.

g. Evaluate the efficacy of genetically-manipulated natural enemies of pest insects and weeds in appropriately sized field experiments.

6. Resource Needs:

a. Expertise in the apppropriate fields of entomology.

b. Expertise in classical genetics, cytogenetics, population genetics, gene cloning, biochemistry, and molecular biology.

c. Stable long-term commitment to funding, personnel, and resources for genetic studies.

7. Selected References:

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Discussion Group F.2

Chairman: Richard Soper

Team Members: George Fassuliotis, Robin Huettel, George Papavizas, and Nader Vakili

1. Title:

Genetic Manipulation and Engineering: Fungi to control insects, plant pathogens, nematodes and weeds

2. Problem Description and Importance:

Although wild strains of fungi have shown considerable promise for biocontrol (insects, pathogens, nematodes, weeds), with few exceptions, there is nothing in the literature indicating that any efforts have been made to improve effectiveness and other desirable characters of biocontrol agents by conventional genetics, gene-splicing, plasmid transfer, or any other approaches. Techniques have been developed that greatly increase our abilities to identify, isolate, modify, and move genes from one cell to another to improve production of drugs, chemicals, and accentuate valuable characteristics in plants and animals. Such techniques, and the acquired knowledge of microbial genomes (gene structure, organization and expression), have not yet been used to engineer biocontrol agents. Limited research has been done with bacteria and viruses, but nothing at all with fungi. If we are to develop "super-biocontrol agents," we must learn how to regulate genes, particularly the group of genes that code for activities responsible for biocontrol ability, find ways to move genes from one organism to another, and determine which genetic make-up gives superior biocontrol under normal and adverse ecosystems.

3. Status of Science and Technology:

a. Biotechnology of biocontrol agents is in its infancy. The recent advances in molecular genetic technologies developed for industrially and medically important fungi (yeast, *Trichoderma*, *Aspergillus*, *Penicillium*) can be used to study genome modifications in fungi. However, there is little or no information on identification, mapping and isolation of genes contributing to the biocontrol capabilities.

b. DNA transformations of plant cells mediated by *Agrobacterium tumefaciens* Ti plasmid and yeast have been demonstrated. Fusion of protoplasts has been accomplished in a few selected cases of microorganisms, but not extensively in those fungi that have potential as biocontrol agents. If biotechnology is to give rise to utilization of fungi for biocontrol, we must adapt and expand the techniques from studies with prokaryotes to understand the molecular genetics of fungal biocontrol agents.

c. Technologies have been developed to improve end-product production from primary and secondary metabolites such as amino acids to secondary macromolecules such as enzymes in filamentous fungi. These developed technologies can be used to study genome modificiation of fungi (e.g., Nematophthora, Fusarium, Verticillium, and Paecilomyces for nematode control; Trichoderma, Gliocladium, Talaromyces, Sphaeronaemella for plant disease control; Beauveria, Hirsutella, and Entomophthorales for insect control; and Phytophthora and Colletotrichum for weed control). However, very little is known about these fungi and knowledge must be acquired on how to isolate genes, modify their structures and determine how the genes that are responsible for biocontrol and other desirable characters are expressed. Strain improvememt in Aspergillus species has resulted from selection techniques and use of natural genetic variation. Chemical selection agents have also been used to increase enzyme output. Many of these selection techniques may be suitable for strain improvement in the fungi but understanding nuclear determination and stability are important.

4. Research Objectives:

a. Identify, select, increase, and preserve the genes controlling desirable traits of biocontrol fungi.

b. Manipulate genes of targeted biocontrol fungi through selection, mutagenesis and recombination to enhance desired characteristics; select model biocontrol fungi for genetic engineering.

c. Develop methods and identify vehicles for gene transfer.

5. Recommended Approaches in ARS:

Genes and their management is just one aspect of the new technology. Both current and future applications depend on other technologies that complement genetic engineering to expand its application. Basic research tasks in this area encompass broad disciplines within the fields of genetic engineering and molecular biology. Complimentary biotechnologies will be needed for significant advancement. The following experimental approaches need to be applied:

a. Use genetic methods from the fields of classical genetics (population, quantitative, biochemical, mendelian), manipulate genomes (e.g. mutagenesis) to enhance fungal variation, and substantially broaden the bases for desirable gene pools.

b. Isolate and identify DNA of biocontrol fungi and its section containing the coded sequence of genes responsible for biocontrol and other desirable traits; and prepare libraries of gene maps.

c. Develop fundamental knowledge of nucleic acids, genes, chromosomes, and extranuclear cell organelles; and of coding properties, transcriptions, and translation of gene-coded information in biocontrol fungi.

d. Develop techniques for in vitro gene splicing and cloning, interspecific and intergeneric gene transfer, and modifications; for in vitro culture of protoplasts, cells, tissues, and the regeneration of fungi; for synthesizing RNA, complementary DNA and vice versa; and for screening recombinant DNA clones by nucleic acid hybridization.

e. Develop fundamental knowledge and techniques to fuse protoplasts or to transfer plasmids from one protoplast to another (vectors for gene transfer and expression) in order to construct desired genetic recombinants.

6. Resource Needs:

There is no research group currently in ARS which addresses the problem of genetic manipulation of fungal biocontrol agents. To accomplish the above objectives, interdisciplinary teams consisting of a fungal geneticist, molecular geneticist, molecular biologist, and biochemist are needed. Three teams should be formed and placed in existing research groups rather than in a centralized facility. (i.e., 1. Plant pathogens and nematodes, 2. Insect pathogens, and 3. Weeds.) The interaction and scientific support of existing plant pathologists, nematologists, insect pathologists, fungal physiologists, and mycologists are required for the achievement of these goals. The target fungi to be researched are sufficiently different to warrant the establishment of different teams.

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Discussion Group F.3

Chairman: Robert Faust

Team Members: Carlo Ignoffo, Phyllis Martin, Robert Owens, and Howard Waterworth

1. Title:

Genetic Manipulation and Engineering to Develop New Strains of Prokaryotic Biocontrol Agents.

2. Problem Description and Importance:

Prokaryotic biocontrol agents can be divided into three general categories: (a) those agents showing promise in laboratory tests (viruses, viroids, and unculturable bacteria such as Bacillus penetrans); (b) prokaryotes that show promise in field studies (species of baculoviruses, B. sphaericus, B. moritae and Zanthomonas); and (c) agents that have demonstrated usefulness in biocontrol programs (B. popilliae, B. thuringiensis, Heliothis NPV, and Lymantria NPV). For those organisms in group (a) the use of currently available selection, biochemical and/or genetic techniques should aid in overcoming cultivation problems. For those prokaryotes falling under group (b) an understanding of the genetic basis for pathogenicity and/or toxicity should be useful in attempts at improving the commercial production, efficacy, and stability. Group (c) agents that have demonstrated usefulness in current biocontrol programs could be genetically enhanced by gene engineering techniques to tailor them to the consumers specific needs. Obviously, knowledge of the genome (e.g. gene structure, organization, and expression) and the mechanisms and virulence factors involved with the mode of action are prerequisites for any attempts to genetically select and/or engineer a prokaryote biocontrol agent into an effective product. Novel technologies for gene manipulation developed with other microbes (e.g., in the industrial and medical fields) are now available and directly transferable for engineering prokaryotic agents to control insects, nematodes, weeds and other noxious agricultural and human pests. Thus, any successful genetically-engineered control agent can be immediately used to increase their effectiveness against major or minor pest systems.

Since the phenotypes of prokaryote control agents reflect their genetic information, it is important that we obtain fundamental information about: (a) the structural organization of the chromosomal and extrachromosomal genomes of these prokaryotes; and (b) how gene organization effects expression, recombination stability, and possible repetitive DNA sequences of the genome.

3. Status of Science and Technology:

Industrially useful microorganisms, as well as those pathogenic for higher organisms, form the basis for much of the new molecular genetics. In contrast little is known about the structural organization of the chromosomal and extra-chromosomal DNA of prokaryotes having

promise for use in biocontrol programs. Recent research on the genetics of important prokaryotes showing promise as biocontrol agents has been concentrated on the spore-forming bacteria and a few insect viruses with principal efforts on several subspecies of B. thuringiensis and the baculoviruses (i.e., NPV of Autographa, Heliothis, and Lymantria). For example, investigators at several laboratories have isolated toxin genes from plasmids of B. thuringiensis and cloned them by recombinant DNA techniques into E. coli and B. subtilis. These cloned genes have been used as probes to localize toxin genes in several other subspecies of B. thuringiensis that express the entomocidal crystal toxin to lepidopteran insects. Also, these cloned genes have been recently sequenced. It has been shown that indigenous and foreign plasmid DNA can be transformed into B. thuringiensis using protoplasts, conjugation-like transfer, and transduction systems. The complete genome of a baculovirus (Autographica) has been genetically mapped and cloned and studies are underway to genetically map the NPV of Heliothis and Lymantria. Promotor genes coding for the polyhedral protein have even been used for the production of human interferon in insect tissue culture cells. Little, if any, investigations have been reported on the genetics of other prokaryote biocontrol organisms.

4. Objectives:

   a. Isolate and identify new promising prokaryote control agents.

   b. Identify, select, isolate, copy and preserve the genes of prokaryote control agents that express those traits we desire to manipulate or transfer.

   c. Characterize gene structure and gene expression.

   d. Develop methods for gene transfer into prokaryotes and into select eukaryotes (e.g., crop plants, algae, etc.) to enhance desirable characteristics.

   e. Manipulate genes through selection, recombination, or genetic engineering to enhance the desired characteristics (e.g., pathogenicity, toxin formation, stability, persistence, host range, and production feasibility).

5. Recommended Approaches in ARS:

   Since several commercial models of biocontrol agents (e.g., B. thuringiensis and the baculoviruses of Heliothis and Lymantria) as well as new genetic technology from other disciplines are currently available, the following experimental approaches are recommended:

   a. Use classical genetic methodology for manipulating genomes (e.g., mutagenesis) to enhance microbial variation and host range and to substantially broaden the desirable gene pool.

b. Develop fundamental knowledge of the nucleic acids components responsible for desirable traits (genes, chromosomes, and extranuclear cell organelles) of prokaroyte biocontrol agents.

c. Develop fundamental knowledge of gene expression including control of transcription, translation and post-translational modification.

d. Develop fundamental knowledge and techniques for in vitro culture of protoplasts, cells, tissues, and the regeneration of organisms; for synthesizing complementary DNA from RNA and vice versa; and for screening recombinant DNA clones by nucleic acid hybridization.

e. Develop fundamental knowledge and techniques for in vitro gene splicing and cloning, and for transferring chromosomal DNA and plasmids from one organism to another (vectors for gene transfer and expression) in order to construct genetic recombinants of biocontrol agents with the most advantageous combination of desirable traits.

6. Resource Needs:

a. Scientists experienced in classical genetics and molecular biology with particular emphasis on molecular genetics, gene cloning, in situ DNA hybridization, and biochemistry (20 SY).

b. Expertise in molecular genetics and biochemistry of protoplasts and eukaryotes with additional expertise in the appropriate fields of microbiology, entomology, insect and plant pathology, nematology, and weed science (18 SY).

c. State-of-the-art instrumentation and equipment is needed to conduct these investigations.

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Discussion Group G.1

Chairman, David Dame

Team Members: Richard Arbogast, Roger Fuester, James Kelleher, and Dave Perkins

1. Title:

Develop Criteria for Selection of Natural Enemies for Research: Insects to control insects

2. Problem Description and Importance:

There are currently no standard criteria that can be applied in selecting natural enemies for biological control research. Economic importance of the target pest as well as ease, effectiveness, cost, and environmental impact of other control methods already in use may be taken into account, but this is not always done. Nor are the characteristics of the natural enemy itself, such as suitability for mass rearing at reasonable cost, alternate host requirements, impact on beneficial or endangered species, or its dispersal capabilities always given adequate consideration. Other important aspects, such as the current complex of pests and natural enemies in the field and taxonomic needs (affinities, distribution, related species, etc.) are not always considered. Field releases of natural enemies sometimes have been made without developing background information necessary to avoid predictable barriers to successful field experimentation. Moreover, natural enemies have occasionally been collected overseas when cooperator commitment was inadequate in the United States to assure proper release and to assess the control agent. To make maximum use of limited resources, we need a set of criteria that can be applied in making preliminary evaluations of candidate biological control agents before costly research programs are undertaken. These criteria should include characteristics of the target pest and the natural enemy, as well as acceptability of currently used control measures. While assessment of a wide variety of parameters is not always required, depending on the specific situation, multiple criteria analysis is recommended to provide the greatest probability of adequate assessment.

3. Status of Science and Technology:

a. Historically, selection of natural enemies for research has been an empirical process. In classical biological control projects, virtually all natural enemies (exclusive of hyperparasites) which were found attacking the target pest during overseas exploration were introduced in the hope that one or more would become established and quickly control the pest. Because of this policy, on a world-wide basis only about 30 percent of the species imported have become established. In spite of the fact that this compares favorably with numbers of insecticidal agents that actually become registered, administrators often perceive biological control as a high-risk gamble. In augmentative biological control projects, ease of rearing the natural enemy has often been considered the primary factor in selecting natural enemies and factors such as tendency to

disperse and host-finding ability have been de-emphasized. As a result, only a few target pests have been controlled effectively using augmentative approaches. Therefore, there is a general perception that biological control is a technique that works once in a while, but cannot be relied upon to yield consistent results.

b. The existing empirical approach has been widely criticized, and it is clear that a more methodical approach is needed in selecting natural enemies so as to increase the percentage of successes in biological control. This need is now especially acute because rising energy costs tend to raise food production costs excessively; biological control generally requires considerably less energy input for implementation. Because of political expediency, many of the theories and procedures of biological control have not been subjected to experimental examination, thus perpetuating the use of the empirical approach.

c. Establishment of reliable criteria for selection of natural enemies will encourage a more experimental approach to resolving a number of biological control concepts and controversies such as:

   1. Are polyphagous natural enemies better than those that are host specific (or vice versa)?

   2. Do we need more background studies before proceeding with introduction or augmentative projects?

   3. Are we taking advantage of all biotypes within a species that might be useful?

   4. How well will a given natural enemy fit into existing control practices?

d. New techniques in taxonomy population genetics, modeling genetic fingerprinting, and other fields should be integrated into development of sound criteria for selecting natural enemies that offer the greatest potential for use in biological control programs.

4. Objectives:

a. Development of a software Expert System, i.e., a computerized weighting system to aid in selection of natural enemies and in selection of particular projects for biological control.

b. Development of information compiled at the BIIL Documentation Center, Beltsville, MD, and at BIRL, Newark, DE, to serve as a historical data base for analysis in providing guidelines for estimating the probability of success or failure based on actual experience. Input to the computer should be retroactive to the earliest available data.

c. Improved sampling methodology. Besides intensified research to improve quality and quantity of data, methods are needed to improve sampling efficiency, both in laboratory and field. This is especially important because of limitations on funds and data collecting time.

d. Development of protocols for evaluating interspecific competition and for assessing the potential for vectoring of pathogens.

e. Increased use of modeling. Determine quality and quantity of data needed for useable models.

f. Development of better protocols for the assessment of ecological synchrony of crop plants, pest insects, and natural enemies.

g. Development of protocols to genetically monitor introduced organisms. Individuals from the natural enemy population evolving from the original organism introductions or from cultures used in augmentative releases should be monitored periodically to "fingerprint" them and determine deviation from the original organism. Electrophoresis could serve this purpose, among other techniques.

h. Development of protocols for description of food webs of natural enemies during the early phase of projects to determine alternate hosts and possible effects on other pest species or beneficial species.

i. Development and improvement of existing techniques to use tracers to determine food material of pest species, predators, and parasites.

5. Recommended Approaches in ARS:

Criteria for selection of natural enemies for research should depend on analysis of available information on economic impact of the target species and on biology, ecology, biological control potential, safety, and interactions with beneficial organisms of the potential biocontrol agents before release in the U.S. Collation and analysis of this information requires a multidisciplinary team approach in order to assure both thoroughness of coverage and adequate perspective on the overall subject. ARS should utilize the team approach to collect and assess data and to determine appropriate criteria for selection of arthropod natural enemies of those insect pests identified as highest priority problems. Specific funds should be allocated to support the part-time involvement of specialists, e.g., taxonomist, economist, zoogeographer, pathologist, ecologist, computer specialist, statistician, etc., not only in the original decision to embark on a formal program but also in research and documentation phases. There should be an appropriate balance of biological control projects both at locations and ARS-wide, leaving some flexibility at the location levels for development of documentation on problems not identified as highest priority. Firm commitments should be required by cooperating units in order to assure continuity of projects and timely replacement of scientists and staff members lost by reassignment, retirements, etc. The following experimental approaches should be continued and/or implemented:

a. Enhanced computer technology to assess newly acquired data, analyze data from past successes and failures, and provide capability for population simulation and analysis of strategy.

b. Improved sampling methods to expedite laboratory and field assessment of potential biocontrol agents, and to provide more accurate surveillance and monitoring capabilities at less cost; and improved tracer technology to provide better information on host-prey interactions.

c. More complete biological studies to enhance capability of assessing adequacy of encounters between natural enemies and hosts in relation to habitat, phenology, and synchrony of activity patterns and to characterize the ecology of the host and the natural enemy.

d. Strengthen taxonomic support for biocontrol research teams to assist in confirmation of species and biotype determination, voucher specimens, and produce joint publications.

e. Provide improved characterization of host and natural enemy genome by karyotype determination, isozyme analysis and other relevant monitoring techniques; conduct biotechnological efforts to select suitable behavioral characterists for natural enemies, e.g., greater dispersal potential or improved search intensity.

6. Resource Needs:

a. To meet the objective of historical analysis and selection systems, there is a need for improved software.

b. To assure adequate testing of unknown species, it is necessary to provide additional quarantine facilities and in some cases to upgrade the security of existing facilities.

c. To provide genetic monitoring, there is a need for instrumentation for electrophoresis, etc.

d. A Screening Team from NPS (i.e., Steering Group) is required to select from among the proposals for implementation (proposals to be submitted on standard IA/ARS forms).

e. This interdisciplinary approach requires a more realistic travel policy, to provide greater research efficiency, increase the probability of successful biotype collection and enhance cooperative efforts within the Agency and with other institutions.

f. Increased funding is required to enable arrangements for cooperative agreements with appropriate collaborators to expand collection, exploration, and evaluation capabilities.

g. Expertise and other supporting staff is required for computer analysis and modeling, genetic monitoring, insect pathology, etc.

7. Selected References:

None

Discussion Group G.2

Chairman: Jack DeLoach

Team Members: Paul Quimby and Raymond Taylorson

1. Title:

Development of Criteria for Selection of Insects to Control Weeds: Insects to control weeds

2. Problem Description and Importance:

A more efficient and logical system is needed to select potentially successful insects as control agents of weeds in order to speed the process of introduction, reduce the costs of development, and to better utilize the limited financial and personnel resources.

Explorations in foreign countries for natural enemies to control target weeds usually reveal many (sometimes several hundred) insects and several plant pathogens and other organisms that attack the plant in different ways. The most important question for the explorer is which few among the many possibilities are the "best" to introduce. The two main criteria in making this decision are safety (the organism should not attack nontarget beneficial plant species) and effectiveness (the organism should control, or help to control, the target weed at a density below the economic threshold). Acquiring sufficient biological, ecological, and host range data by experimentation to evaluate any one candidate insect for introduction has been estimated to cost 5 SYs. The cost of acquiring such information on all the organisms attacking a plant probably greatly exceeds the resources available on any biocontrol project. Some method of screening that would allow the selection of the most promising few organisms at an early stage in the research and before the extensive laboratory testing has been done, is needed.

The selection process is complicated because sometimes organisms that apparently were not the major controlling factor near the site of origin provided the best control when introduced into a new area. Many of the candidate insects that have been extensively tested and released in the U.S. have not become established in the field. Consideration of the proper criteria should allow the selection of organisms that would more easily become established.

3. Status of Science and Technology:

Presently, searches for natural enemies are made by both short (a few days to a few weeks) or long (a few months) trips by U.S.-based scientists (who may not be experienced in foreign exploration), by ARS employees in permanently-based overseas laboratories (presently located in Rome, Buenos Aires, Paris, and Seoul), by contract with organizations of other nations, or through PL-480 projects. After promising insects are discovered, extensive host range and biological testing is then done. If possible, most of the early testing is done in the overseas

laboratories both for safety (to prevent a possibly dangerous insect from escaping into the U.S.) and because it can be studied under more natural conditions since the insect does not need to be confined in quarantine within its native distribution. Only one or two U.S. scientists are usually located in these labs, and they must usually act independently and with minimal contact with cooperating scientists in the U.S. A system of evaluating the biocontrol potential of natural enemies would greatly benefit both the U.S.-based explorer and the scientists in the overseas labs.

In the early years of biological control, control agents (insects) were selected by the subjective judgment of trained biologists with long experience.

Harris (1973) devised a system for evaluating the various insect enemies of a weed at an early stage in the research. His system assigned a numerical value to each of a set of criteria (each at several degrees), the sum of which provided an effectiveness value for the insect which could be used to compare it with other insects. The criteria were: 1) host specificity, 2) direct damage inflicted, 3) indirect damage inflicted, 4) phenology of attack, 5) number of generations, 6) number of progeny per generation, 7) extrinsic mortality factors, 8) feeding behavior, 9) compatibility with other agents, 10) distribution, 11) evidence of effectiveness as a control agent, and 12) size of agent.

Goeden (1983) modified Harris' system by arranging the criteria into three groups: I) initial assessment of destructiveness in native range, II) suitability as a biocontrol agent, and III) potential effectiveness in area of introduction. He also changed the numerical values assigned to some criteria, added criteria on ease of culture, colonization history of agent, and ecoclimatic similarity, and removed the criterion on compatibility with other agents which he judged difficult to evaluate.

These evaluation systems have not been universally accepted by biocontrol workers and most current projects apparently do not use them as a basis for selecting control agents for introduction. Also, the real effects of the various criteria, and their relative importance in influencing the desirability of a control agent for introduction, have not been established experimentally nor documented by past experience.

Many of the past and current concepts and practices remain controversial. For example, some workers have proposed that control agents should be collected from the climate zone most similar to that of the proposed release site, while others point out that many insects can adjust to a wide range of climates; or that the most effective control agents might be those that attack closely-related species different from the target weed species while others believe that high host specificity is essential; or that as many species of natural enemies as possible should be released while others caution that competition between them may reduce their overall effectiveness as well as to increase the risk to nontarget plants; or that zero damage should be allowed on nontarget plants while others propose that slight or moderate damage to plants of little economic or ecological value might be acceptable; or that single-plant starvation tests are important while others rely entirely on multiple-choice preference tests to determine host range.

A variety of methods for testing the host range of control agents in confined conditions have been used, none of which represent the true behavior of the organisms in the field, with the result that some potentially useful and safe control agents may have been excluded from introduction. Biological control scientists in certain countries have a different philosophy and methodology of testing that streamlines the introduction process; some aspects of these systems might be adaptable to U.S. needs.

4. Research Objectives:

a. Develop theoretical and practical concepts to determine the optimal locations in the world where the most effective and safe control organisms for target weeds may be found.

b. Develop methods of searching and collecting that will discover control organisms efficiently.

c. Develop theory and technology to select, at an early stage in the research project, the most effective and safe candidate natural enemies from among the many found during explorations, so that the limited financial and manpower resources available can be concentrated on the best few candidate control agents.

d. Develop reliable theory and methodology for testing the safety and efficacy of candidate organisms.

5. Recommended Approaches in ARS: (It should be understood that many of the following approaches will involve thorough correlative follow-up studies of biocontrol agents after their release.)

a. Determine the importance of selecting natural enemies from world climate zones similar to those where control is desired.

b. Develop concepts to determine the site or origin of a weed and the relative merits of searching for natural enemies at the center of origin or on the periphery of the natural distribution of the weed.

c. Determine the relative importance of stress placed on different types of target weeds (annuals, perennials, woody, aquatic, etc.) by natural enemies that attack different plant organs, different developmental stages of the plant, or that attack the plant at different times during the year.

d. Determine extent to which removal of the parasitoids, predators, and pathogens that attack an insect control agent in its native area will allow its increased efficacy in the release area.

e. Develop principle for predicting effects of native and naturalized parasitoids, predators, and pathogens in reducing the efficacy of introduced control agents.

f. Examine the relative values of control agents with different survival strategies (high vs. low fecundity, single vs. multiple generations, constant vs. periodic pressure on the plant) in controlling weeds.

g. Determine the relative efficacy of monophagous vs. oligophagous insect species as control agents.

h. Determine the principles of complementarity or antagonism among multiple biocontrol agents of given weeds; test the validity of competitive exclusion and the interference of control organisms by native homologs.

i. Determine how "acceptable host specificity" should be defined and the amount of damage that can be tolerated on native or naturalized nontarget plants.

j. Develop methodologies for obtaining and interpreting the information, especially host range, in the field during initial explorations that can be used to evaluate the insects' effectiveness and safety as a control agent.

k. Develop methodologies for host-range testing so that unsafe organisms will be detected and safe organisms will not be rejected because of artifacts of the testing procedure.

l. Determine how to select candidate control agents with the attributes that allow their establishment and increase after release, with special attention to matching the insect biotypes with biotypes of the target weed, diapause, aestivation, and migratory and other behavioral characteristics.

6. Resource Needs:

Expertise in host plant/insect interactions, biogeography, ecological physiology, population biology, insect behavior and biosystematics.

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Zwolfer, H., M. A. Ghani, and V. P. Rao. 1976. Foreign exploration and importation of natural enemies. pp. 189-207. IN C. B. Huffaker and P. S. Messenger (eds.) Theory and Practice of Biological Control. Academic Press, New York.

Discussion Group G.3

Chairman: James Vaughn

Team Members: William Nickle and Patrick Vail

1. Title:

Develop Criteria for Selection of Natural Enemies for Research Pathogens to Control Insects.

2. Problem Description and Importance:

The safe, effective use of microbial agents in the control of pest insects requires a high level of knowledge about the basic life processes of the microorganism. Also, the relationship between the microorganism and the target pest, the biology and ecology of the pest, and possible effects on other forms of life must be understood. The results of well planned and executed basic and applied research are necessary in order to achieve many of the objectives related to the use of microorganisms in insect pest management.

In order to be of maximum usefulness, this fund of accumulated knowledge must be continually replenished in anticipation of new problems in insect pest control. This research would cover the following subject areas: (1) the morphology, biochemistry, and pathology of the microorganism and the stability of these characteristics in various conditions of production and use; (2) The genetic factors of the microorganism that regulate mode-of-action in a susceptible host; (3) development of efficient and safe production methods; (4) study of the effects of habitat, pest biology, and environmental factors on the effectiveness of the pathogens; (5) the specific factors which determine host range. The development of any successful microbial agent will depend upon the completion of the studies referred to above. Also, considerable thought should be given as to how technology will be transferred. Special applications, timing, formulations, and equipment considerations must be thoroughly explained and understood by the users. As with many other new control techniques sufficient expertise does not exist in the field to allow this transfer to occur smoothly and effectively.

3. Status of Science and Technology:

At the present time there are more than a dozen pathogens registered or near registration for use in the control of insect pests. Seven are viruses, four are bacteria, and one each of the fungi and the protozoa. Six entomogenous nematode preparations are presently marketed for pest insect control. Currently these pathogens are used primarily against phytophagous, Lepidoptera, but some are effective for controlling selected aquatic stages of pests of man and animals, grasshoppers, important soil pests, and post-harvest pests. The commercial products that incorporate the bacterium *Bacillus thuringiensis* var. *kurstaki* have achieved wide acceptance as effective control agents for a variety of Lepidoptera. Basic research into the

improvement of production methods and in the development of more effective strains has increased the effectiveness and reduced the cost of this product. The bacterium, Bacillus popilliae, provides effective control of the Japanese beetle but the supply is limited because the microorganism cannot be produced except in the host insect. Several fungi are also under investigation as possible control agents for a variety of grasshoppers, beetles and aphids that are serious pests. Similarly, there have been partial studies on some protozoa that have good potential for use in controlling such pests as the fall armyworm, beet armyworm, and the spruce budworm. There have been several viruses isolated which show good potential for controlling such important pests as the codling moth and the Indian mealmoth. Entomogenous nematodes have shown potential against insects inhabiting soil, water, and crops. Thus, there are some pathogens for which there has been sufficient research to establish a high potential for future use as control agents. However, those pathogens already registered and the few others that are near registration represent less than 1% of the total number of microorganisms that have potential value in controlling pest insects. Future direction of research in this area requires the development of definitive criteria for the prioritization and selection of additional pathogens to increase our biocontrol arsenal.

4. Objectives:

a. Economic Impact of the Pest. The crop value and/or losses due to the pest(s) is sufficient to justify the development of pathogens as control measures. The target arthropod is the key pest on one crop or is a significant pest on several crops. Economic potential may be increased by use on several crops or insects.

b. Suitability of Pathogen as a Solution to the Problem. Adequate knowledge of the pest; life stages, habitat, and population dynamics are known. This information is used to determine at what stage the insect needs to acquire the pathogen in order to provide control. Certain insects may not be amenable to control because of feeding habits, stage that is a pest, etc. Insects inhabiting certain habitats such as water, soil and storage, or insects with certain feeding habits such as internal feeders and sucking insects would dictate the choice of pathogens.

c. Potential Use Patterns: Highly virulent pathogens can be used in prophylactic methods or to control immediate problems. Alternatively, pathogen(s) may possess other desirable characteristics such as persistence in the pest population or reduction in reproductive potential and other debilatative effects that may be used in population management strategies. How the pathogen will interact with other existing mortality factors should be considered.

d. Compatability of Pathogen(s) with Current Insect Control and Other Production Practices. Can the pathogen be used with existing application equipment? Will it replace or be an added control procedure to the current ones? Will other cultural practices have to be altered in order for the pathogen to be used, e.g, timing may interfere with irrigation schedule or pathogen may be incompatible with other agrochemicals.

e. Safety and Environmental Impact. Taxonomic relationships indicate little chance of vertebrate involvement. Natural occurrence indicates little effect on beneficial organisms in the same environment.

f. Potential for Commercialization. Will the pathogen be commercially attractive when its production costs, methods of application, efficacy, and marketing potential are determined?

5. Recommended Approaches in ARS:

N/A

6. Resource Needs:

N/A

7. Selected References:

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Discussion Group H.

Chairwoman: Katherine Reichelderfer

Team Members: Richard Aldrich, William Day, Ray Rebois, and Joe Sasser

1. Title:

Economic Research Relevant to Biological Control: Economic research to support planning, research and development of biological control technology.

2. Problem Description and Importance:

a. Economic research here refers to estimation of values associated with pest problems and their control, to assist public and private decision making with regard to allocation of resources for biological control. Public fund availability limits the range of biological control possibilities that can receive research and development efforts. The success of any developed biological control technology is ultimately judged by whether it is practical for use by farmers, and if it can compete economically with other control methods. There is need, therefore, to both incorporate sound economic information into criteria for identifying priority areas of biological control research, and utilize relevant economic measures to test and demonstrate the success of biological control research products. However, few biological control strategies have received extensive economic study. Social and environmental benefits and cost reductions resulting from development of biological alternatives to current pest control practices have not generally been quantified in ways that provide useful information to decision makers. Agency support for biological control is less rapid and enthusiastic than it might be if the technology's economic consequences were better known. The competitive farmer has no incentive to adopt biological control if it is not clearly demonstrated to be at least as profitable as and/or safer than current practices.

b. Because there are few appropriately trained economists who have both the interest and opportunity to work on biological control issues, it is difficult for biological control researchers to obtain economic input. Opportunities are limited for involving agricultural economists, housed in separate agencies or departments from biological scientists, in cooperative research efforts. There are, moreover, career and institutional disincentives for economists to provide supportive input to biological research in lieu of performing more strictly intradisciplinary research. Historically, biological control researchers have not sought economic input in the early stages of research programs. As a consequence, there is little documentation as to the effects of specific biological control strategies on yield and quality of output--important economic indicators of the strategies' success.

3. Status of Science and Technology:

The state-of-the-art of pest management economics is sufficiently advanced to address many economic issues regarding biological control planning, research, development, and evaluation. Even so, fewer than ten in-depth studies have been conducted in an agricultural economic framework to compare emerging biological control options with conventional practices. This scarcity of background and precedent work is a function of the problems indicated under 2-b.

4. Objectives:

a. To help assure that maximum benefits are derived from research expenditures for biological control.

b. To demonstrate economic feasibility of biological control techniques in comparison with present and alternative methods.

c. To improve profitability of specific biological control technology by developing optimal strategies for promising technologies' utilization.

5. Recommended Approaches in ARS:

a. Involve economists in applicable phases of biocontrol research, from planning through execution and evaluation stages.

b. Develop and maintain an index of relative economic importance of alternative biocontrol targets.

c. Project the expected costs of emerging pest problems that could be mitigated through early application of a biological control approach.

d. Collect and interpret basic data defining the current pest loss, input use and control cost situations on crops or in areas where biological control experimentation is to be conducted, prior to initiation of tests. This will assure baseline data are available for eventual economic evaluation of experimental results.

e. Conduct economic analyses in conjunction with biological control experiments to determine, as appropriate, such things as: optimal level of control, economic thresholds, and optimal rate and timing of biological control, as a means of maximizing the potential profitability of techniques' implementation.

f. Conduct evaluations to measure, in monetary terms, the effectiveness of biological control agents in field tests.

g. Determine the total, long-term and annual costs and benefits of alternative plant and animal protection systems for which technical feasible biological control alternatives have been developed.

6. Resource Needs:

The approaches outlined above require the input of agricultural economists familiar with pest management research. While some consultative economic input will be useful, achievement of indicated research objectives will require a significant concentration of time and effort on the part of a number of economists. ARS does not currently employ a group of economists who could work in this area. The principal resource needs can be met either through employment and internal support of a core of 4-6 agricultural economists, or through allocation of sufficient funds for extramural and/or interagency cooperative research agreements with agricultural economists.

7. Selected References:

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Discussion Group I.1 and 2

Chairmen: Gary Cunningham and John Henry

Team Members: Ralph Bram, Jack Coulson, Ben Kopacz, William McGaughey, Meritt Nelson, and Al Undeen

1. Title:

Cooperation on Application and Integration of Natural Enemies: Insects and pathogens to control insects, weeds, and plant pathogens.

2. Problem Description and Importance:

Application and integration of insects and pathogens for control of insects, weeds, or plant pathogens are complex processes that require cooperation between researchers within ARS as well as between ARS and other research agencies and institutions. Inadequate cooperation increases the prospect of failure to efficiently utilize the biological control organisms and strategies. The basic reasons for lack of cooperation include (a) lack of communication between ARS research personnel, between ARS and other agencies and institutions, and between research personnel in other disciplines; (b) inadequate mechanisms for establishing biocontrol research priorities with ARS, with full involvement of concerned research personnel, and in responding to and coordinating ARS priorities with the priorities of other agencies and user groups; (c) failure to recognize that implementation of new technologies by action agencies, extension, and industry is dependent on a logical sequence from research to methods development and usually requires coordination and supporting research throughout the project; and (d) inadequate allocation of research resources to solve highest priority problems with sufficient flexibility to respond to new problems or research opportunties when they occur.

3. Status of Science and Technology:

a. Communication between ARS research personnel and between ARS and other agencies and institutions currently results from NPS biological control teams, regional and interagency commitees such as S135, selected national or commodity coordination groups, professional society meetings, regional biocontrol committees such as those in the southern and northeastern regions, CRIS and other reports, and various periodic interdisciplinary workshops.

b. Biological control priorities within ARS are based on the current 6-Year Implementation Plan, the recommendation of the recent CSRS interdisciplinary biocontrol workshop at Las Vegas, the current biocontrol planning workshop, ARS program reviews, program review and critiques of other agencies, and NPS liason function with other agencies on research needs.

c. The transfer of new technology from ARS research to action agencies, extension, and industry often results from joint participation in pilot-test programs, biological control technical review groups,

completion of safety tests, and feedback from action agencies and industry on additional research needs and ARS technology transfer program.

d. ARS research resources currently are allocated on the basis of the 6-Year Implementation Plan, internal redirections, permanent budget increases, and temporary budget increases from grants, TUPF funds, pilot-test funds, interagency project funding, and various international cooperative programs.

4. Objectives:

a. Improve intra- and interdisciplinary scientist communication in ARS and between ARS and other agencies, research institutions, and user groups (for example: action agencies, trade and commodity organizations, farmers, and industry).

b. Develop mechanisms for establishing biological control research priorities in coordination with other research agencies, institutions, and user groups.

c. Develop mechanisms to assure continuity of biological control research from basic research to full implementation by user groups.

d. Allocate sufficient resources to research problems of highest priority to insure project completion.

5. Recommended Approaches in ARS:

Objective (a):

1. Develop a network of key scientists within each discipline to provide a technical resource for the NPS Biocontrol Team in lieu of the ARS Working Group on Natural Enemies (WGNE).

2. Reactivate the Departmental Working Group on Biological Control Agents (WGBCA) on a continuing basis, (or establish a similar coordinating group at the Departmental level).

3. Improve means to identify available resources in any particular problem area and the scientists who are doing relevant research in that area and develop the means to better coordinate their communicaton and research activities.

4. Establish a realistic travel policy which will promote the improvement of communication and coordination resulting in greater biological control reseach productivity.

5. Increase the frequency of interdisciplinary biological control workshops (eg., every 2 years) to include other agency and institutional representation.

6. Encourage greater ARS participaton in such coordinating groups as the International Organization for Biological Control (IOBC), professional society groups and others, and encourage active ARS liaison participation in the North American Plant Protection Organization (NAPPO).

7. Encourage ARS scientists to contribute to and make greater use of the ARS Biological Control Documentation Center.

Objective (b):

1. Continued annual review and updating of portions of ARS 6-Year Plan relevant to biological control by NPS Biocontrol Team in communication with a network of key scientists (See 5.a.1 above).

2. Encourage the NPS Biocontrol Team to continue coordination activities with technical input by the network of key scientists.

3. Establish a policy of holding interdisciplinary Biological Control Planning Workshops every 2 years, to include representation from other research agencies and institutions and user groups.

4. Improve NPS Biocontrol Team liaison with other research agencies and user groups through the WGBCA and other mechanisms (see 5.a.2 above)

5. Meet emergency needs using the existing plan developed by ARS and action agencies.

Objective (c):

1. Develop government-user cooperatives for specific biological control applications in private sectors where commercialization is not attractive.

2. Develop mechanisms for liaison between key scientists and NPS with action agencies, user groups, and industry at early stages of biological control projects to assure that the research objectives interface with methods development and user needs.

3. Establish a funding mechanism for tier 1 testing of potential biological control agents which will fulfill EPA requirements for field evaluation to insure the proper sequence from research to application of promising microbials.

Objective (d):

1. Increase emphasis on pilot-test programs to fully evaluate biological control organisms.

2. Encourage increased ARS applications for competitive grants for conducting research on application and integration of biocontrol agents.

3. Invite input by key scientists and user groups as technical resources when making decisions on resource allocations.

4. Encourage scientist participation in the development of laboratory resources management plans.

5. Proceed with program redirection in accordance with the 6-Year Implementation Plan.

6. Encourage suggestions for new research thrusts from scientists through proper channels.

7. Encourage suggestions for new research thrusts from user groups.

6. Resource Needs:

a. Increased pilot-test funds (5.d.1).

b. Funds for tier 1 safety tests of insect and weed microbial agents (5.d.4).

c. Consider increased ARS funds earmarked for research in support of action agency programs, on a project-by-project basis (5.c.3).

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Discussion Group J.

Chairwoman: Amy Rossman

Team Members: Burton Endo, Richard Humber, and Paul Marsh

1. Title:

Taxonomic Research on Fungi in Support of Biological Control: Fungal taxonomy in support of biocontrol research

2. Problem Description and Importance:

Fungal taxonomy provides the foundation upon which biocontrol research with fungi can develop. Many biocontrol fungi cannot be identified, even by experienced mycologists, and the majority of groups containing biocontrol fungi need further taxonomic study. Traditional taxonomic research on biocontrol fungi combined with appropriate non-traditional taxonomic approaches to specific groups should be undertaken immediately. Authoritative taxonomic references and expanded knowledge of interrelationships between fungal organisms will greatly expedite research on biocontrol fungi.

Significant advances in the use of insects as biocontrol agents has paralleled support for insect taxonomy. In contrast, biocontrol using fungi is a relatively new and understaffed field of research which remains without adequate taxonomic support. Every major project studying the use of fungi for biocontrol should include funding for work on the systematics of the organisms involved. The probability of finding and developing effective biocontrol fungi will be greatly increased by applying the predictive aspects of systematic knowledge.

3. Status of Science and Technology:

The general status of knowledge concerning fungi as potential biocontrol agents varies widely among broad classes of target organisms. More than 250 taxonomically diverse fungal genera have species that parasitize or kill insects and arachnids. The host specificities of individual entomogenous species range from exceptionally broad (affecting hosts in many orders or families) to highly specialized (attacking single host species or genera). Free-living nematodes are attacked by a few dozen taxonomically diverse fungi, but only a handful of species are known to attack phytoparasitic nematodes; the promise of these few potentially useful pathogens discovered through limited surveys strongly justifies expanded efforts to survey for nematophagous fungi. The importance of fungal antagonists and pathogens of phytopathogenic fungi has only recently been appreciated, and broad surveys for such fungi have barely begun. Obligately phytopathogenic fungi are widely known and offer promise for controlling many weeds; facultative phytopathogens are much less well understood but deserve greater attention as biocontrol agents of plants.

No generalization is possible about the levels of taxonomic/systematic understanding of biocontrol fungi. Among entomogenous fungi, for instance, the taxonomy of some key genera is stabilized, while some of the largest and possibly most significant groups of fungi desperately need taxonomic and systematic attention. The taxonomy of the few known nematophagous fungi is reasonably well worked out. Taxonomic and systematic information for the hyphomycete fungi which may be most useful to control destructive fungi must be regarded as poor. The taxonomy and systematics of obligately phytopathogenic rusts and smuts are fairly well stabilized, but the facultatively phytopathogenic conidial fungi are, again, poorly understood. No comprehensive identification manuals exist for fungi useful in biocontrol except for rusts, smuts, and nematophagous fungi.

Many powerful systematics techniques are available but are not yet being applied by mycologists. As the basic taxonomic understanding of individual fungal groups accumulates, special effort should be made to apply phytogenetic analysis, cytological, developmental, and biochemical information for further resolutions of relationships.

4. Objectives:

a. Prepare comprehensive monographs to synthesize biological information on key genera of fungi used to control insects, phytopathogenic fungi, nematodes, and weeds. Such monographic studies include aids for species identification, the elucidation of relationships with allied fungal groups, and predictions about key biological characters of important biocontrol fungi. The resulting monographs must be mycologically rigorous as well as useful to nonmycologists.

b. Obtain specimens of groups of biocontrol fungi through surveys and world-wide exploration for biocontrol fungi. This is prerequisite for adequate monographic studies. Natually occurring pathogens for target hosts tend to occur at the geographical centers from which those hosts radiated.

c. Obtain, maintain, and distribute cultures of biocontrol fungi. These cultures will be deposited in appropriate ARS culture collections and/or the American Type Culture Collection (Rockville, MD), and made available to all interested ARS and other biocontrol and biotechnology research programs. Where not already available, develop special cultural techniques for the isolation and maintenance _in vitro_ of obligate pathogens. Cultures of biocontrol fungi will be incorporated into the National Plant Germplasm System.

5. Recommended Approaches in ARS:

a. A fungal taxonomist working specifically in the area of research on non-entomopathogenic biocontrol fungi should be hired immediately by ARS. Such expertise is urgently needed by ARS and non-ARS scientists with whom a biocontrol fungal taxonmist would work cooperatively.

b. Fungal taxonomists should be involved in the planning and/or execution of all biocontrol projects using fungi, particularly if survey or exploration for new biocontrol agents is involved.

c. Cultural techniques need to be modified or developed for obligate pathogens not yet available *in vitro*. Effective cultural and long-term storage of fungal germplasm without genetic changes will permit ready distribution of cultures and facilitate research with biocontrol fungi.

d. World-wide surveys of all fungal groups with biocontrol potential should be supported. There is a particular need to discover and to culture new entomopathogens and hypocrealean anamorphs that parasitize rusts.

e. Classical taxonomic methods which depend on morphology and host specificities are necessary for basic monographic studies of fungal taxa with strong biocontrol potential. These groups includes Ascomycetes in the Hypocreales (e.g. *Nectria*, *Hypocrea*, and *Hypomyces*), and Clavicipitales (e.g., *Cordyceps*, *Torrubiells*, *Hypocrella*) and their imperfect (conidial) stages (e.g., *Aschersonia*, *Fusarium*, *Gliocladium*, *Hirsutella*, *Paecilomyces*, *Trichoderma*, *Verticillium*). Another group of fungi meriting immediate attention are the dark-spored hyphomycetes.

f. Biochemical techniques (e.g, fatty acid analysis, serology, isozyme electrophoresis, DNA hybridization, restriction endonucleases) should be used where the basic taxonomy of a fungal group is understood and where further systematic refinements are needed (e.g., the resolution of species complexes).

6. Resources Needs:

a. Maintain and strengthen centers of excellence on the systematics of fungi attacking phytopathogens, weeds, nematodes, or insects. There is an immediate need for specialists in the taxonomy of non-entomogenous hyphomycetes with biocontrol potential.

b. Support foreign and domestic exploration and surveys for potential biocontrol fungi to be included in comprehensive monographic studies. Areas of host origin and greatest species diversity should be thoroughly collected for natural pathogens.

c. Increase existing ARS capacities for deposition and distribution of fungal cultures with potential biocontrol value. Actively augment such repositories by solicitation of cultures from other laboratories, and by isolation from foreign and domestic sources. Enter into cooperative agreements with ATCC to provide for exchange of cultures used in systematics studies and distribution to the scientific community.

d. Develop personnel resources with expertise in biochemical techniques which are becoming increasingly important in systematics of fungi. The application of these techniques to biocontrol fungi may answer difficult questions on biological differences between isolates of closely related species.

Anticipated Impacts of Planned Accomplishments:

The most immediate impacts of systematics studies on biocontrol research are to increase the efficacy of ongoing research programs, to enhance the clarity of communication among biocontrol research programs, to facilitate future work by offering better guidance for choices of fungi to be studied, and to increase stabilization of fungal taxonomy. Solution of systematics problems will serve to stimulate new research on utilization of biocontrol fungi.

Existence of improved references for diagnoses of biocontrol fungi will benefit mycological systematics by relieving them of some routine diagnostics duties and by stimulating a flow of new and interesting material into their research programs.

Expanded collections of fungal germplasm will support further systematics studies and will better serve all research programs using fungi for biocontrol.

7. Selected References:

Ainsworth, G. C., F. K. Sparrow, and A. S. Sussman (eds.). 1973. The Fungi: an advanced treatise, vols. 4a-b. Academic Press, New York.

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Discussion Group K.

Chairman: James Duke

Team Members: Robert Perdue and Sara Rosenthal

1. Title:

Heterogenicity in Weed Populations in Relation to Biological Control

2. Problem Description and Importance:

Heterogenicity in weed populations can markedly influence the outcome of biological control events. In addition to classical morphological variations (e.g., hairiness, waxiness) in weed populations, there can be important variations in the ecology, phenology and phytochemistry of such weed populations. Any of these, alone or in concert, can conceivably alter a biological control scheme. The crown-boring weevil, Phrydiuchus tau, for example, is specific to its weedy host Mediterranean sage, Salvia aethiopis, because of morphological differences from other closely related plants. The weevil is unable to live in the herbaceous crowns of North American Salvia spp. and is restricted to its woody, perennial host.

With each weed species producing hundreds, perhaps thousands, of chemicals, it is not surprising to find many phytochemicals in a given species that may kill, repel, deter feeding of, alter development of, or attract various arthropod natural enemies. There are dozens of chemicals, any one of which may render a weed species relatively resistant to a fungus, insect, and/or nematode. Recent studies have documented heterogenicity in plant species for allelochemicals and phytoalexins. Morphologically similar phenotypes may have significantly different levels of allelochemicals (or phytoalexins following fungus invasion). For example, hypericin, a chemical found in Hypericum spp., including Klamathweed, H. perforatum, acts as an attractant for specialized herbivores. As the concentration of hypercin may vary from plant to plant so does the plants' susceptibility to herbivore damage. Spike rushes, Eleocharis spp., among other plants, have been shown to release allelopathic chemicals. A sod formed of these plants, 2-6 cm tall, can prevent the establishment of larger, rooted, submerged weeds that would otherwise interfere with water flow in canals.

For good biological control the phenological state of the target plant is important, often critically so. Seed destruction by insects within thistle flowerheads depends on synchronization of seed predator oviposition with bud formation of the thistles. Once a biological control agent has arrived in its target host, it must be effective, not just survive under the climatic, edaphic, and biotic regime in which its host is considered a pest. Plants and their herbivores have coevolved; it may be difficult to distinguish whether the heterogenicity of the plant or that of the herbivore is involved.

3. Status of Science and Technology:

Although the relevant sciences (basically taxonomy, ecology, genetics) are quite well developed in academia, some of the recent innovations in these fields have not been fully implemented by ARS. Some of these specialized sciences, although operational, have not been fully utilized in intra-agency cooperative efforts; such collaboration seems best for biological control research. These fields are changing rapidly. Biological weed control, e.g. is evolving from an observational methodology to a more experimental science. Taxonomists and geneticists are turning to newer methods of electrophoresis and chromatography to study variation. Hypotheses on the influence of plant quality and environmentally induced variation on herbivore:host relationships are leading to a better understanding of population dynamics.

For row crops, scientists and pharmaceutical companies have developed technology for mass production of mycoherbicides such as Collego for control of northern jointvetch. Milky spore disease is, of course, an earlier technological development for control of several insects. More recently Bacillus thuringiensis has proven effective against fungal plant pathogens. Classical biocontrol is being developed by academic and government scientists and rarely evolves into industrial technology.

Scientific and Technological Advances to Ameliorate Problem. Some of the newer techniques used as tools ancillary to classical taxonomy and ecology could be embraced by ARS to study heterogenicity of weeds. These include, but are by no means limited to, electrophoresis of different kinds, (now evolving), DNA-hybridization, chromotography, chromosome staining, environmental mensuration, etc.

4. Objectives

a. Better basic understanding of intraspecific weed variation, including morphological, phytogeographical, cytological, biochemical, ecological, and phenological variation.

b. Better basic understanding of the coevolution of herbivore and pathogen host relations.

c. Better basic understanding of the chemical and ecological parameters of a weed population which might lead to host switching.

d. Basic research on the mechanisms and probabilities of developing resistance to herbivores and pathogens.

e. Development of biological control for high-priority weeds.

5. Recommended Approaches in ARS:

The classical taxonomic approach is necessary in the initial research on target-host relationships. However, new taxonomic techniques should be applied and integrated with newer biochemical, cytological, ecological, and genetic approaches.

The program should develop a basic methodology for measuring and reporting heterogenicity within a weed population. In biological control research, more attention should be paid to this heterogenicity, in both agent and target, in choosing whether to use single or multiple introductions and in testing host specificity.

Data bases should be developed containing fundamental data on heterogenicity of weeds in their centers of origin, centers of diversity, and areas of introduction.

Expand fundamental taxonomic data on hosts and biological control organisms so as to include phytochemical, ecological, and phenological data to complement the classical morphological data usually accumulated by conventional taxonomists.

6. Resource Needs:

Expertise in taxonomy, with emphasis on the modern techniques, which have heretofore been little used in ARS, is the primary need. A multidisciplinary approach, involving ecologists, taxonomists, and biochemists is mandatory requiring inhouse or extracurricular expertise in many newer techniques.

7. Selected References:

Barrett, S. C. H. 1982. Genetic variation in weeds. pp 73-98 *in* Charndattan, R. and H. L. Walker, eds, Biological control of weeds with plant pathogens. John Wiley & Sons, New York 293 pp.

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Discussion by Lars Anderson

1. Title:

Biological control of aquatic weeds using herbivorous fish.

2. Problem Description and Importance:

The costs associated with aquatic weed infestations and their control amount to more than $1.2 billion dollars annually. Few herbicides have been available during the past 15 years and few new aquatic herbicides have been registered for use. Mechanical methods are extremely expensive and do not provide long-term solutions. Current costs for control of aquatic weeds in ponds, lakes and canals are $200-$700 per acre. In many multiuse aquatic systems, chemical methods cannot be used due to potential environmental impacts and potential herbicide residue in drinking water. Likewise, irrigation water conveyance systems often cannot be exposed to herbicides because of potential injury to crops. For these reasons, development of biological control techniques using fish is extremely important as a means for aquatic weed management that has low probability of adverse affects on the environment.

3. Status of Science and Technology:

   a. Two types of fish have been used successfully to reduce aquatic weed infestations: *Tilapia* (various species) and White Amur (*Ctenopharyngodon idella*). *Tilapia* is limited to warm waters (less than 60°C) whereas the White Amur can tolerate a wide range of water temperature. White Amur is also a more efficient forager and readily converts plant biomass to (edible) fish biomass. Some information on feeding selectivity is available, but relationships of environmental condition (temperature, stocking density, water flow) to feeding are not well known.

   b. The primary impediment to development of herbivorous fish biocontrol is the fact that these fish are exotic species and their release has been curtailed or banned, by many state agencies. This action resulted from a concern that White Amur could reproduce and adversely impact other fisheries. However, the development of a sterile hybrid fish in 1979 led to several small-scale field tests which eventually showed the hybrid to be ineffective in consuming weeds. A recently (1983) developed triploid (sterile) White Amur has produced excellent results in preliminary tests in Florida. More small-scale field tests are planned for 1984 in Florida, but research funding for studies in other areas is lacking. In essence, a potential new tool is becoming available, but no one knows how best to use it.

4. Research Objectives:

   a. Develop basic information on feeding efficiency and preferences, growth rate and reproductive capacity of triploid White Amur under various temperatures and flow rate conditions.

   b. Develop methods to manipulate triploid White Amur for management of aquatic weeds.

   c. Develop improved methods for grow-out of triploid White Amur from fry to size useable for aquatic weed management.

5. Recommended Approaches in ARS:

   a. Develop basic knowledge on feeding efficiency, feeding preferences, growth rates and reproductive capacity of "sterile" triploid White Amur. Small scale feeding trials at various temperatures and stocking densitites will be used. Histological examination of gonadal tissues will be used to determine reproductive status.

   b. Effects of water flow and periodic partial dewatering (simulated drawdown) will be examined using model canal systems.

   c. Controlled field tests in well secured ponds and small irrigation canals will be conducted to establish operational feasibility for control of aquatic weeds.

6. Resources Needed:

   a. Expertise in rearing and handling of White Amur or similar fish, fish biology and reproduction.

   b. Expertise in aquatic weed biology, ecology and management.

   c. Facilities for maintaining White Amur, conducting feeding research and field scale efficacy testing. Access to a variety of secured ponds and flowing water sites is essential.

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Discussion by C. Jack DeLoach

1. Title:

Development of Criteria for Selection of Weed Species for Classical Biological Control Research

2. Problem Description and Importance:

The selection of target weeds for research in the past has been determined largely by various imprecise procedures such as pressures from user organizations. This process probably identifies some of the major problems but may overlook problems that affect less well organized user groups. It may also not utilize appropriate expertise to examine the entire array of problems and select the ones that have both the greatest chance of success and that provide the most benefit.

The selection of the "best" few weeds for research, out of the many that need control, is of great importance since the cost of a control program is considerable, the potential benefits are great, and the technical feasibility of achieving control varies greatly with different weeds. The selection of weeds that represent less than the optimal ratio of success potential and benefits to be gained results in the inefficient utilization of a large amount of manpower and financial resources, as well as the postponement of research on other more urgent and promising weeds.

Andres (1977) reported that an average of 3.5 SY were required to test each of the 14 weed-feeding insects released in the U.S. between 1956 and 1976. Since control usually requires more than one insect, the average cost per weed controlled was ca. 12 SY or $1 million at 1977 prices. Harris (1979) estimated the cost of controlling one weed in Canada at 18.8-23.7 SY based on all Canadian projects between 1950 and 1976; 2.0-3.6 SY were spent on overseas study, 0.3 SY on indigenous surveys, 4.0-7.5 SY on screening studies, and 12.5 SY on post release studies. He postulated that a weed that was amenable to biocontrol would be worth the cost if it caused damages of $150,000 or more annually. He also stated that all previous projects that targeted weeds that were amenable to biocontrol and formed dense stands over large areas, reduced the weed by at least 90% if the programs had been energetically pursued, adequately financed, and sufficient time spent.

A basic premise for control is that natural enemies must exist somewhere in the world that are capable of controlling the weed and are sufficiently host specific not to damage plants on which their attack is not wanted.

Classical biocontrol scientists have long postulated that some types of weeds are much easier to control than others: (1) introduced weeds are thought to be easier to control than native weeds, (2) weeds of stable ecosystems (rangelands, aquatic environments) are easier than weeds of cultivated crops, (3) broadleaf weeds are easier than grasses, and (4) perennial weeds are easier to control than annuals.

There are four basic factors that must be evaluated in selecting a weed for research. The first of these is the potential for successful control. This is determined largely by the known or probable existence of natural enemies that are host specific and capable of controlling the weed. This is greatly influenced by the site of origin and distribution of the weed species and the weed genus; for example, if the weed species and all other members of the genus occur naturally in North America, then little chance exists for finding natural enemies that could be introduced. The second factor is the amount of damage caused by the weed. This includes several aspects such as the area infested and density within that area, potential for spread, losses caused at different densities, productivity of the area infested, competition with crops and forages for water, nutrients or light, toxicity to livestock, allergenicity to humans, damage to recreational areas, loss of soil water, and cost of control. The third factor is an estimate of beneficial values of the weed. This includes their use as ornamentals, wildlife food or cover, honey production, a source of fuel, lumber, pulpwood, or fiber, a source of medicines, drugs, or other chemicals, for human food, or for supplemental livestock grazing. The fourth factor is a determination of the ecological values such as its place in the plant community, its place in the food chain of animals (especially mammals and birds), the number of closely related plant species (especially beneficial species or endangered species in the same genus) that might be at risk of attack by control organisms not absolutely specific to the weed species.

3. Status of Science and Technology:

DeLoach (1976) discussed several of the factors involved in the selection of native weeds for biological control, and most of the factors would apply equally well to introduced weeds. DeLoach (1980) made a beginning attempt to create a model for the selection of target weeds of southwestern U.S. rangelands by evaluating the damage caused, direct beneficial values, several ecological factors, and the potential for finding effective control agents. Unfortunately, good estimates of damage caused is available for only a few major weed species and that usually is only in certain crops or areas of the country. Few economic studies have been done and even these often are based on opinion surveys rather than on hard data. Great difficulty exists in attempting to integrate unpriced values (Sinden and Worrell, 1979), such as aesthetic values in parks, values as food and cover for wildlife, and other ecological values, into a model together with dollar estimates of damage caused and beneficial values for ornamentals, firewood, etc. The only comprehensive work on wildlife food plants is now over 30 years old (Martin, et al., 1951).

Two recent breakthroughs in assessing the damage caused by rangeland weeds are the development of remote sensing techniques capable of identifying and measuring the density of individual weed species (Everitt, in press a and b) and the large project of the USDA-Soil Conservation Service to measure the occurrence of all noxious brush species on Texas rangelands (R. H. Johnson, SCS, Temple, TX, personal comm.).

4. Research Objectives:

   a. Develop the methodology for estimating the amount of damage caused by the candidate weed.

   b. Develop the methodology for estimating the direct beneficial value of the candidate weed to man.

   c. Develop the methodology for estimating the various values of each candidate weed in the ecosystem.

   d. Develop the methodology for estimating the success potential of biological control for each candidate weed.

   e. Develop a model for evaluating the various harmful, direct beneficial, and ecological values and the success potential for each target weed as a basis for resolving the conflicts of interest, for ranking weeds in priority order for research, and for assessing the economic and ecological and consequences of control.

5. Recommended Approaches in ARS:

   a. Develop remote sensing or other methods for measuring the densities of target weeds throughout their range and of allocating the total acreage to density classes.

   b. Develop methodology to measure the losses caused by target weeds at different densities and in different climatic and/or agricultural productivity zones.

   c. Develop methods for measuring and assessing economic data on the direct beneficial values and their value as ornamentals.

   d. Develop the methodology for estimating the effect on the plant community of reducing the abundance of target weeds by specifiec amounts.

   e. Develop methods for estimating the value of target weeds in the food chains of animals, the impact that specific reductions of the weed would have, and the extent to which other plants would be substituted if the weed density were reduced.

   f. Compile and evaluate available data on usage of target weeds and closely related plants by wildlife for food, shelter, and nesting sites.

   g. Determine the effects in the ecosystem of reducing nontarget, closely related weeds, including endangered species.

   h. Develop theory and methodology for evaluating the potential for finding effective and safe natural enemies that could be utilized for biological control.

i. Assemble a team of modelers, systems analysts, entomologists, weed scientists, plant ecologists, and wildlife scientists to develop a model in which presently available information can be evaluated, and into which new information can be added as it becomes available, to evaluate the effects of biological control on the various harmful, beneficial, and ecological values of target weeds.

6. Resource Needs:

A team approach with expertise in modeling, economics of natural resources and agriculture, weed scientists, remote sensing, entomologists, plant ecology, range science, social science, and systems science, to evaluate the top priority weeds and resolve all the conflicts of interest in each major agroecosystem, such as southwestern rangelands, northeastern pastures, and southeastern row crops, etc.

7. Selected References:

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PRIORITIES TEAMS

A. CROPLAND WEEDS

Aldrich, R. J.

Acock, B.
Bouse, L. F.
Cunningham, G.
Connick, Jr., W.
Millhollon, R. W.
Quimby, P. C.
Schweizer, E. E.

B. AQUATIC WEEDS

Anderson, L. W.

Buckingham, G.
Center, T.

C. WEEDS IN FORAGES, GRAZING LANDS, AND NONAGRICULTURAL LANDS

Bovey, R. W.

Andres, L.
Bruckart, W. L.
DeLoach, J.
Duke, J.
Linscott, D. L.
Rosenthal, S.
Taylorson, R. B.

D. CROP INSECTS (divided into 3 categories)

Drea, J. J. (Overall Chairman)

D.1 - Tree Crops (D. E. Meyerdirk)

Dysart, R.
Gassner, G.
Greenstone, M.
Hopper, K.
Humber, R.
Moorehead, G.
Witz, J.

PRIORITIES TEAMS
(continued)

D.1.2 - Insect Pests of Graminaceous and Forage Crops (G. R. Sutter)

Andaloro, J.
Ashley, T.
Day, W.
Drea, J.
Henry, J.
King, E.
Lewis, L.
Lewis, W. Joe
Puttler, B.
Stinner, R.
Vaughn, J.

D.1.3 - Row and Specialty Crops (H. Graham)

Coulson, J.
Dougherty, E.
Goodpasture, C.
Hung, A.
Ignoffo, C.
Jones, W.
Lopez, J.
Nickle, W.
Powell, J.
Ridgway, R.
Schroder, R.
Smith, J.

E. POST HARVEST INSECTS

Vail, P.

Arbogast, R. T.
Dulmage, H.
Labeda, David
McGaughey, W. H.

F. INSECTS AFFECTING MAN AND ANIMALS

Bram, R. A.

Dame, D.
Faust, R.
Harris, R. L.
Knipling, E. F.
Marsh, P.
Miller, R.
Patterson, R.
Reichelderfer, K.
Seawright, J. A.
Undeen, A.

PRIORITIES TEAMS
(continued)

G. SOILBORNE PATHOGENS

Papavizas, G.

Adams, P.
Ayers, W.
Civerolo, E.
Howell, C. R.
Lewis, J. A.
Lumsden, R. D.
Marois, J.

H. FOLIAR PLANT PATHOGENS

Spurr, H.

Knudsen, G.
Nelson, M.
Rossman, A.

I. POST HARVEST PLANT PATHOGENS

Wilson, C.

Moline, H.
Wells, J.

J. NEMATODES

Endo, B.

Brodie, B. B.
Dowler, W. D.
Fassuliotis, G
Huettel, R.
Rebois, R.
Rodriguez-Kabana, R.
Sayre, R.
Sasser, J.

K. INSECTS ON ORNAMENTALS, SHADE TREES, AND FORESTS

Soper, R.

Anderson, R.
Dysart, R.
Hoy, M.
Kelleher, J.
Martin, P.
Metterhouse, B.
Shapiro, M.

PRIORITIES SUMMARY A.

Chairman: Richard Aldrich

Team Members: Basil Acock, Fred Bouse, Gary Cunningham, William Connick, Jr., Rex Millhollon, Paul Quimby, and Edward Schweizer

I. Problem Title:

Cropland Weeds

II. Problem Statement:

Losses caused by weeds and the cost of their control in crops amount to $16 billion annually. This approximately 10 percent loss in crop value has persisted for the last 25 or more years in spite of significant advances in chemical weed control. Alternate approaches to chemical control are needed because of loss in herbicidal effectiveness due to breakdown in soil with repeated use and the development of resistant biotypes, undesirable soil persistence of some herbicides and related environmental concerns, and the increasing costs of herbicide introduction. Biological weed control can be an alternative to herbicides as well as a component in integrated weed management systems. Biocontrol may provide an effective way of limiting spread of emerging problem weeds, both those recently introduced and those formerly introduced species now spreading in response to changes in production and weed control practices. Also, biocontrol may help prevent seed production by weeds in surrounding noncrop areas thereby reducing infestation of cropland. Finally, biocontrol offers the potential of more lasting control than with herbicides. Interest in biocontrol of weeds has grown rapidly and two biocontrol agents (both pathogens) have reached the point of commercial use in crops (Colletotrichum gloeosporioides, sp. Aeschynomene and Phytophtora palimivora). Research must be expanded to identify additional, practical, effective biocontrol agents and to develop methods for fully effective integrated weed management systems in field and horticultural crops.

III. Criteria for Priorities:

The following sets of criteria were used in the prioritizaiton of cropland weeds as targets for biological control research. Attempts were made to consider as many as possible for each species even though it is recognized that because of the absence of factual data in many cases, estimates were required.

1. Economics:
   a. Extent of infestation
   b. Magnitude of losses
   c. Type of losses
   d. Effectiveness of control
   e. Cost of current control
   f. Potential to become a greater problem: (yield losses, quality, etc.).

2. Biocontrol Potential:
   a. Relatedness to crops, native plants, endangered spp., etc.
   b. Degree of control required
   c. Preferred biological control approach
   d. Susceptibility to biological control
   e. Availability of agents
   f. Previous efforts on biocontrol and technological feasibility

IV. List of Priorities:

1.	Velvetleaf	(*Abutilon theophrasti* Medic.)
2.	Common cocklebur	(*Xanthium strumarixum* L.)
3.	Canada thistle	(*Cirsium arvense* (L.) Scop.)
4.	Ipomoea spp.	(*Ipomosa* spp.)
5.	Yellow nutsedge	(*Cyperus esculentus* L.)
6.	*Solanum* spp.	(*Solarium* spp.)
7.	Sicklepod	(*Cassia obtusifolia* (L.))
8.	Itchgrass	(*Rottboellia exaltata* L.F.)
9.	*Euphorbia* spp.	(*Euphorbia* spp.)
10.	Johnsongrass	(*Sorghum halepense* (L.) Pers.)
11.	Purple nutsedge	(*Cyperus rotundus* L.)
12.	Parasitic weeds	(*Cuscuta* spp., *Orobanche* spp., *Striga* spp.)
13.	Prickly sida	(*Sida spinosa* L.)
14.	Amaranthus spp.	(*Amaramtaus* spp.)
15.	Convolvulus spp.	(*Comvolvulus* spp.)
16.	Hemp dogbane	(*Apocynum cannabinum* L.)
17.	Spurred anoda	(*Anoda cristata* (L.) Schlecht)
18.	Balloonvine	(*Cardiospermum halicacabum* L.)
19.	*Ambrosia* spp.	(*Ambrosia* spp.)
20.	Quackgrass	(*Agropyron repens* (L.) Beauv.)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Abutilon theophrasti Medic — Velvetleaf

2. Candidate biocontrol agents (when known and appropriate)

   Fusarium lateritium
   Colletotrichum cociodes

3. Commodities

   Soybeans, sugarbeets, cotton, corn

4. Status of biocontrol research effort:

   a. Past: *Verticillium* wilt showed promise in Wisconsin; bionomic research conducted on *Fusarium lateritium* by H. L. Walker, Stoneville, MS.

   b. Present: Searching India for agents; integrated weed management research in progress with *Fusarium lateritium* (may soon be ready for pilot test on technical feasibility).

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Search China, India, Nepal; also mycoherbicide approach with *F. lateritium* and *C. coccodes*.

6. ARS laboratories involved (present)

   Southern Weed Science Laboratory, Stoneville, MS; Robert Anderson, St. Paul, MN.

7. Other Federal laboratories involved (present/future)

   SRRC (Connick--formulation) and ERRC (Nolan--production)

8. Potential State/University cooperation

   SAES w/S-136; Lehigh University; Delta State University.

9. Suggested ARS contact individual(s) - (Key person)

   P. C. Quimby, Jr., H. L. Walker, Stoneville, MS; R. N. Anderson, St. Paul, MN.

10. Funds required

    $10,000 for foreign exploration (Spencer); $100,000/yr. for 3 years--C/A for external and pathol. in India; $35,000 for domestic C/A's.

11. SY input needed

2.0 (overseas); 1.0 domestic C/A's.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

This was ranked the No. 1 weed problem in crops · ˙th high potential for biocontrol.

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Xanthium strumarium L. — Cocklebur

2. Candidate biocontrol agents (when known and appropriate)

Several pathogens in literature; *Corythemea* sp. (lacebug); South American insects.

3. Commodities

Soybeans, cotton, rice (leaves).

4. Status of biocontrol research effort:

a. Past: Preliminary survey for insects conducted in South America (DeLoach).

b. Present: Initial stages--mycoherbicide approach (Stoneville).

5. Recommended research approaches (augmentation, introduction, pathology, other).

Mycoherbicide approach and introduction of insects from South America for control in marginal areas.

6. ARS laboratories involved (present)

Southern Weed Science Laboratory, Stoneville, MS.

7. Other Federal laboratories involved (present/future)

Hurlingham, Argentina.

8. Potential State/University cooperation

Delta State University, Cleveland, MS; Lehigh University, Bethlehem, PA.

9. Suggested ARS contact individual(s) - (Key person)

P. C. Quimby, Jr.

10. Funds required

$70,000 to renew C/A for 2 years w/Delta State University; $35,000/Hurlingham for 3 years; $5,000 for production contract with Lehigh University.

11. SY input needed

1.0 on C/A; 0.4 SWSL; 0.4 in Hurlingham.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cirsium arvense L. Scop — Canada thistle

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   Crops, pastures, wasteland.

4. Status of biocontrol research effort:

   a. Past: Canada Department of Agriculture--foreign studies; USDA introduced Centorhynchus litura in roots; Altica cardurum on leaves; Rophers cardui on stems. Work with endemic rust Puccinia punctiformis.

   b. Present: Monitoring establishments.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Albany, CA; Beltsville, MD.

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   USDA/CA, OR, WA, ID, MT, WY, and other states.

9. Suggested ARS contact individual(s) - (Key person)

   S. S. Rosenthal, Albany, CA; S. Batra, Beltsville, MD.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.8.1.b
    2.4.9.1.c
    2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

   Ipomoea spp. | Morningglories, annual

2. Candidate biocontrol agents (when known and appropriate)

   Cassid beetles, Bruchid beetle (attack seeds); *Puccinia* spp; *Colletotrichum dematicum* f. sp. *Ipomoearum*; *Alternaria alternata* (tentoxin)

3. Commodities

   Soybeans, peanuts, rice (leaves), horticultural crops.

4. Status of biocontrol research effort:

   a. Past: Work with rusts at U. of AR (not promising).

   b. Present: Initial stage--pathology approach with tentoxin at Southern Weed Science Lab. Initial stage--mycoherbicide approach at N.C. State U. with *C. demetium* on tall morningglory. Survey stage at Southern Weed Science Lab., Stoneville, MS.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation (mycoherbicide); possible introduction of host species insects from South America; pathology (tentoxin from *Alternaria alternata*).

6. ARS laboratories involved (present)

   Southern Weed Science Laboratory (SWSL), Stoneville, MS.

7. Other Federal laboratories involved (present/future)

   Future possible--Hurlingham, Argentina.

8. Potential State/University cooperation

   U. of AR; Delta State Univ., Cleveland, MS; North Carolina State University.

9. Suggested ARS contact individual(s) - (Key person)

   P. C. Quimby, Jr., Stoneville, MS.

10. Funds required

    $30,000 for C/A for 2 years; $15,000/yr. at Hurlingham for 3 years.

11. SY input needed

    0.75 (M.S. candidate, C/A); 0.2 at Hurlingham.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cyperus esculentus L. — Yellow nutsedge

2. Candidate biocontrol agents (when known and appropriate)

   Puccinia canaliculata

3. Commodities

   Most cultivated crops, grain fields, gardens, often in poorly drained areas.

4. Status of biocontrol research effort:

   a. Past: Field and laboratory tests.

   b. Present: Integration studies, scaling up work, fungus specificity studies.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Research is designed to understand how to: 1) produce and store inoculum, 2) introduce (release) the pathogen (timing and inoculum concentration) and integrate the pathogen with other weed control strategies. A better understanding of the specificity of *P. canaliculata* is needed in order to fully implement this organism in control of nutsedge.

6. ARS laboratories involved (present)

   USDA, Coastal Plains Experiment Station, Tifton, GA (Homer Wells); Plant Disease Research Laboratory, Frederick, MD.

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Coastal Plains Experiment Station, Tifton, GA (S. Phatak)

9. Suggested ARS contact individual(s) - (Key person)

   Homer Wells, Tifton, GA; William Bruckart, Frederick, MD.

10. Funds required

    $35,000.

11. SY input needed

    0.2 SY (cooperative agreements--University of Maryland and University of Georgia)

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Solanum spp. e.g. S. carolinense L., S. nigrum L., S. ptycanthum Dun. — Horsenettle, Black nightshade

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   Pinto beans, dry beans, soybeans

4. Status of biocontrol research effort:

   a. Past: Surveys in South America for insects (DeLoach).

   b. Present: Surveys in progress for potential mycoherbicides.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Southern Weed Science Laboratory; Tifton, GA; St. Paul, MN.

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   SAES w/S-136; U. of MN; Delta State University.

9. Suggested ARS contact individual(s) - (Key person)

   P. C. Quimby, Jr., H. L. Walker, R. N. Anderson.

10. Funds required

    $35,000 for C/A.

11. SY input needed

    1.0 through C/A.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.8.1.b
    2.4.9.1.c
    2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   (Cassia) *Senna obtusifolia* L. — Sicklepod

2. Candidate biocontrol agents (when known and appropriate)

   Alternaria cassiae

3. Commodities

   Crops, wasteland, especially soybean, peanut, cotton

4. Status of biocontrol research effort:

   a. Past: Bionomic data developed on *Atl. cassiae*; patent issued.

   b. Present: Development of mycoherbicide *Alt. cassiae* (in pilot test for technological feasibility).

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Mycoherbicide approach.

6. ARS laboratories involved (present)

   Southern Weed Science Laboratory (SWSL), Stoneville, MS.

7. Other Federal laboratories involved (present/future)

   SRRC (Connick--for formulation).

8. Potential State/University cooperation

   N.C State Univ; U. of AR; Clemson; U. of FL; LSU, other universities associated w/S-136.

9. Suggested ARS contact individual(s) - (Key person)

   H. L. Walker or P. C. Quimby, Jr., SWSL.

10. Funds required

    Renewal of pilot test (approx. $85,000) for 1 year and possibly another. $55,000 for third year.

11. SY input needed

    1.1 (Research Associate plus 0.1 PFT)

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

Pest organism	Common name
Rottboellia exaltata L.F.	Itchgrass

2. Candidate biocontrol agents (when known and appropriate)

Pathogens--lead disease and headsmuts.

3. Commodities

Cultivated crops--soybeans, sugarcane, corn, and sorghum.

4. Status of biocontrol research effort:

a. Past: Field testing of Prechslera sorghicola (H. L. Walker and White). Was not highly effective on seedlings.

b. Present: None at present.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Survey foreign sources for pathogens such as head smuts.

6. ARS laboratories involved (present)

Southern Weed Science Laboratory, Stoneville, MS; U.S. Sugarcane Field Laboratory, Houma, LA.

7. Other Federal laboratories involved (present/future)

Plant Disease Research Laboratory, Frederick, MD.

8. Potential State/University cooperation

Louisiana State University.

9. Suggested ARS contact individual(s) - (Key person)

H. L. Walker, Southern Weed Research Laboratory; R. W. Millhollon, U.S. Sugarcane Field Lab.

10. Funds required

Foreign exploration (Millhollon)--$10,000 for 3 trips.
$35,000 for C/A w/LSU.

11. SY input needed

1.0 SY (C/A)

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

<u>Euphorbia</u> <u>spp</u>. e.g., <u>E</u>. <u>maculata</u> L., <u>E</u>. <u>supina</u> Raf., <u>E</u>. <u>heterophylla</u> — Spotted spurge, prostrate spurge, wild poinsettia

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

Cultivated crops, pasture, wasteland.

4. Status of biocontrol research effort:

a. Past: None reported.

b. Present: Surveys in progress for potential mycoherbicides.

5. Recommended research approaches (<u>augmentation</u>, introduction, pathology, other).

6. ARS laboratories involved (present)

Southern Weed Science Laboratory, Stoneville, MS.

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

SAES w/S-136.

9. Suggested ARS contact individual(s) - (Key person)

P. C. Quimby, Jr., and H. L. Walker, Stoneville, MS.

10. Funds required

No additional.

11. SY input needed

No additional.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Sorghum halepense (L.) Pers. — Johnsongrass

2. Candidate biocontrol agents (when known and appropriate)

   Sphacelotheca cruenta (Head smut) and other pathogens and insects both native and foreign.

3. Commodities

   Practically all cultivated crops.

4. Status of biocontrol research effort:

   a. Past: Field testing of head smut.

   b. Present: Testing of head smut is continuing.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   1) Develop methods to mass insect field populations of johnsongrass with head smut.
   2) Evaluate rhizome--feeding insect (Metacranbuz spp.) that occurs in Israel and is also under study there by Dan Gerling (Tel Aviv Univ.).
   3) Survey foreign sources for other pathogens and insects.

6. ARS laboratories involved (present)

   U.S. Sugarcane Field Laboratory.

7. Other Federal laboratories involved (present/future)

   Southern Weed Science Laboratory.

8. Potential State/University cooperation

   Louisiana State University (Gordon Holcum); University of California-Berkeley (Steven Lindow).

9. Suggested ARS contact individual(s) - (Key person)

   R. W. Millhollon

10. Funds required

    $75,000 (possible for BARD proposal).

11. SY input needed

    0.5

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cyperus rotundus L. — Purple nutsedge

2. Candidate biocontrol agents (when known and appropriate)

   Heterodera mothi (nematode); Bactra verutana (moth). (Possibly rust pathogens)

3. Commodities

   Cultivated crops,.gardens, fallow fields.

4. Status of biocontrol research effort:

   a. Past: Pilot test completed on Bactra verutana.

   b. Present: Initial studies in progress with Heterodera mothi.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation for Bactra and Heterodera.

6. ARS laboratories involved (present)

   Southern Weed Science Laboratory.

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   N. R. Spencer, Stoneville, MS

10. Funds required

    Current hard money adequate at present.

11. SY input needed

    No change.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.8.1.b
    2.4.9.1.c
    2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cuscuta spp., *Striga asiatica*, *Orobanche ramosa* — Dodder, Witchweed, Branched Broomrape

2. Candidate biocontrol agents (when known and appropriate)

   Buckeye Butterfly, Agromyzid Fly, *Phytomyza orobanchiae*.

3. Commodities

   Corn, sorghum, sugarcane, tomato, pepper, celery, carrots, tobacco.

4. Status of biocontrol research effort:

   a. Past: In 1960's striga research was done in India under PL-480. *Orobanche* research has been done in Yugoslavia and the Meditterranean region.

   b. Present: Unknown. Research is occurring at the University of Khartoum-Sudan.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation with native buckeye butterfly, *Precis coenia*. Introduction.

6. ARS laboratories involved (present)

   Not known.

7. Other Federal laboratories involved (present/future)

   APHIS Methods Development Laboratory.

8. Potential State/University cooperation

   NCSU and Clemson for witchweed. Texas A&M with Dr. M. Chandler (*Orobanche*).

9. Suggested ARS contact individual(s) - (Key person)

   APHIS contact--Dr. R. Eplee, Methods Development, Whiteville, NC.

10. Funds required

    $150,000/

11. SY input needed

    1.0 SY.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

For witchweed--augmentative release of native butterfly will require mass rearing, handling, and dispersal elements.

For branched broomrape--introduction of exotic biocontrol agents will require quarantine approach and non-target testing.

2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Sida spinosa L. — Prickly sida

2. Candidate biocontrol agents (when known and appropriate)

   Colletotrichum malvarum; *Fusarium lateritium*.

3. Commodities

   Cultivated crops, especially cotton.

4. Status of biocontrol research effort:

   a. Past:

   b. Present: Patent issued on both organisms. Need to do integrated weed management research yet; pilot tests needed for technological feasibility.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Mycoherbicide approach.

6. ARS laboratories involved (present)

   Southern Weed Science Laboratory, Stoneville, MS.

7. Other Federal laboratories involved (present/future)

   SRRC (Connick-formulation); ERRC (Nolan-production)

8. Potential State/University cooperation

   U.of AR; Delta State University; other SAES associated with S-136; Lehigh University.

9. Suggested ARS contact individual(s) - (Key person)

   P. C. Quimby, Jr.

10. Funds required

    $35,000 for C/A for 2 years; $2,500 for production contract with Lehigh University.

11. SY input needed

    0.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

<u>Amaranthus spp</u> — Redroot pigweed
e.g., <u>Aretroflexus, A. hydridus</u>

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

All crops (horticultural and agronomic)

4. Status of biocontrol research effort:

   a. Past: Tried inoculative appr. moving <u>Disonyeha glabrata</u> from Mississippi to North Dakota (Quimby)--not promising.

   b. Present: Surveys in progress (S-136) for potential mycoherbicides.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Mycoherbicide appears a possibility.

6. ARS laboratories involved (present)

Southern Weed Science Laboratory

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

SAES w/S-136

9. Suggested ARS contact individual(s) - (Key person)

P. C. Quimby, Jr., and H. L. Walker, SWSL.

10. Funds required

No additional

11. SY input needed

No additional

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Convolvulus spp. — Bindweed

2. Candidate biocontrol agents (when known and appropriate)

   Thecophora seminis convolvuli, *Aceria convolvuli*, *Speringophagus serviceus*.

3. Commodities

   Crops, pastures, wasteland.

4. Status of biocontrol research effort:

   a. Past: Foreign exploration for natural enemies in Europe and Pakistan; surveys also in Canada and USA. Many potential biocontrol agents tested were able to feed on certain sweet potato varieties and native *Colystegia* spp.

   b. Present: Due to conflict of natural enemies feeding on native morningglories and sweet potatoes, it will be difficult to find control agents for this species.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   S. S. Rosenthal, Albany, CA.

10. Funds required

    No additional funds required.

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.8.1.b
    2.4.9.1.c
    2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Apocynum cannabinum L. — Hemp dogbane

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   New crops, meadows, forage crops, wide spread northern and central midwest and northeast - Coming in no-till.

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Native--low biocontrol potential unless predators of close relatives or pathogens can be found.

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Nebraska.

9. Suggested ARS contact individual(s) - (Key person)

   Schrieber.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.8.1.b
    2.4.9.1.c
    2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Anoda cristata (L.) Schlecht — Spurred anoda

2. Candidate biocontrol agents (when known and appropriate)

   Alternaria macrospora and Fusarium lateritium (in combination)

3. Commodities

   Cotton.

4. Status of biocontrol research effort:

   a. Past: Bionomic research completed; patent issued on combination.

   b. Present: Need to do research on integrated weed management systems; perhaps pilot test on technology feasibility in near future.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Mycoherbicide approval.

6. ARS laboratories involved (present)

   Southern Weed Science Laboratory, Stoneville, MS.

7. Other Federal laboratories involved (present/future)

   SRRC (Connick--formulation) and ERRC (Nolan--production)--future.

8. Potential State/University cooperation

   Delta State University, Lehigh University, SAEA associated with S-136.

9. Suggested ARS contact individual(s) - (Key person)

   P. C. Quimby, Jr., and H. L. Walker, Biological Weed Control Research Unit, Stoneville, MS.

10. Funds required

    $200,000 for equipment ERRC; $150,000 for 1 SY ERRC; $35,000 for C/As.

11. SY input needed

    2.0 (0.5 as on 2 C/A's).

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.8.1.b
    2.4.9.1.c
    2.4.9.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cardiospermum halicacabum L. — Balloonvine

2. Candidate biocontrol agents (when known and appropriate)

   Unknown.

3. Commodities

   Soybeans.

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: Preliminary surveys in South America (Hurlingham Lab.).

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Suggest classical approach with insects from South America for control of balloonvine on ditch banks and other marginal areas.

6. ARS laboratories involved (present)

   Southern Weed Science Laboratory.

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   P. C. Quimby, Jr.

10. Funds required

    $15,000 Hurlingham Laboratory.

11. SY input needed

    0.1 initially; more if promising insects found.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.8.1.b
    2.4.9.1.c
    2.4.9.1.d

Growing problem in soybeans because of contamination in harvested crop; prevents certification of seed.

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Ambrosia sp. — Common ragweed (A. artemisiifolia)
Giant ragweed (A. trifida L.)
Western ragweed

2. Candidate biocontrol agents (when known and appropriate)

   Possible in Mexico and South America.

3. Commodities

   Abandoned cultivated land, old pastures, wasteland, and roadsides.

4. Status of biocontrol research effort:

   a. Past: Surveys of natural insect enemies in U.S. made on ca. 6 species of Ambrosia. No active research in U.S.

   b. Present: Promising control in USSR using insects from U.S.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

   Beltsville, MD.

8. Potential State/University cooperation

   University of California, Riverside (R. D. Goeden).

9. Suggested ARS contact individual(s) - (Key person)

   Suzanne Batra.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.8.1.b
2.4.9.1.c
2.4.9.1.d

Conflict of interest as food for songbirds.

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Agropyron repens (L.) Beauv — Quackgrass

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   Field crops, forage crops, & pastures in cool humid regions.

4. Status of biocontrol research effort:

   a. Past: None

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Wisconsin, New York.

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.8.1.b
    2.4.9.1.c
    2.4.9.1.d

PRIORITIES SUMMARY B.

Chairman: Lars W. J. Anderson

Team Members: Gary Buckingham and Ted Center

I. Problem Title:

Biological Control of Aquatic Weeds

II. Problem Statement:

Aquatic weeds cause annual losses and damages to water resources in the United States totaling $1.2 to $3 billion. Those losses result from: blockage of water flow for irrigation and drinking, incapacitation of recreational areas, impediment of aquaculture harvesting, pollution of drinking water, reduction of fisheries habitats, increased siltation of streams and deltas, increased mosquito breeding, blockage of hydroelectric plants, and impeded navigation. For example, the noxious submersed weed hydrilla alone is unchecked and costs all agencies in Florida over $15 million annually and will have cost California and the Federal government over $5.5 million between 1977 and 1984. The seriousness of hydrilla has increased with recent (1983) discoveries of a monoecious strain in several Northeastern States and in the Potomac River.

In spite of the economic impacts of aquatic weeds, few herbicides are available and mechanical costs can exceed $500 per acre or per mile. The cost of developing a new herbicide is currently over $15 million over 10 years; whereas a biocontrol program for water hyacinth, including exploration, quarantine, host specificity testing, and field development of several insects has cost less than $2 million over a similar time period. Therefore, return for invested dollars has been excellent in this and other biological control programs.

III. Criteria for Priorities:

The following set of criteria were used to rank the importance of aquatic weeds for inclusion in biocontrol research. The feasibility of developing biocontrol (Biocontrol Potential) was given equal weight with the economic impact criteria (C.). Within these criteria, all forms of biocontrol were considered, not solely classical methods.

a. Identification

1. Scientific name
2. Common name
3. Family
4. Type: (floating, submersed, emergent, algae)
5. Origin
6. Taxonomic problems

b. Ecology:

1. Infestation habitat
2. U.S. distribution
3. Potential for spread
4. Potential for weedy growth

c. Economics:

1. Extent of infestation
2. Magnitude of losses
3. Types of losses
4. Effectiveness of control
5. Cost of current control (per unit acre or per mile)
6. Impact on public agency water resources.

d. Biocontrol Potential

1. Conflicts of interest
2. Relatedness to crops, native plants, endangered species
3. Degree of control desired
4. Preferred biological control approach
5. Susceptibility to biological control
6. Availability of agents
7. Previous efforts on biocontrol

IV. List of Priorities:

1. Hydrilla (Hydrilla verticillata)
2. Waterhyacinth (Eichhornia Crassipes)
3. Sago pondweed (Potamogeton pectinatus)
4. Eurasian watermilfoil (Myriophyllum spicatum)
5. Filamentous algae (Cladophora, Pithophora, Lyngbya, Spirogyra)
6. American pondweed (Potamogeton nodosus)
7. Schinus (Schinus terebinthifolius)
8. Duckweeds (Lemna, Spirodela)
9. Cattails (Typha latifolia)
10. Waterlettuce (Pistia stratiotes)
11. Parrotfeather (Myriophyllum aquaticum)
12. Waterprimrose (Ludwigia spp.)
13. Egeria (Egeria ensa)
14. Miramar weed (Hygrophila polysperma)
15. Elodea (Elodea canadensis)
16. Phragmites (Phragmites australus)
17. Southern naiad (Najas guadalupensis)
18. Torpedograss (Panicum repens)
19. Melaleuca (Melaleuca quinquenervia)
20. Purple loosestrife (Lythrum salicaria)
21. Coontail (Ceratophyllum demersum)

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Hydrilla verticillata hydrilla

2. Candidate biocontrol agents (when known and appropriate):

   White Amur (Triploid)
   Hydrillia spp.
   Bagous spp.
   Fusarium rosaum (culmurom)
   Parapoynx diminutalis (native)
   Parapoynx spp. (exotic)
   nematodes

3. Commodities:

   Water resources (irrigation, potable, recreational, hydroelectric)

4. Status of biocontrol research effort:

   a. Past (1971-1976)
      1. PL 480: 7-year exploration project in Pakistan and India.
      2. CIBC (1979) 1-year exploration in Africa.
      3. University of Florida cooperative agreement 1981-1984 (Exploration).
      4. University of Florida (White Amur)
      5. California Department of Agriculture (APHIS, ARS White Amur, dwarf spikerush).
      6. Army Corps of Engineers (White Amur)
      7. Pathogen screening.

   b. Present
      1. Florida, California, APHIS, ARS White Amur (Triploid).
      2. Evaluation of foreign insects (ACOE).
      3. ARS dwarf spikerush (*Eleocharis* sp.).

5. Recommended research approaches (augmentation, introduction, pathology, other)

   a. Development of methods for use of Triploid White Amur.
   b. Discovery and development of classical biocontrol agents including insects and pathogens.
   c. Develop methods for using beneficial competitive plant species.
   d. Develop augmentive control agents
   e. Discover and develop native nematodes and pathogens that can be used for augmentive control strategies or for production of toxic metabolites.

6. ARS laboratories involved (present):

   Ft. Lauderdale
   Gainesville
   Davis

7. Other Federal laboratories involved (present/future):

   ACOE (WES)
   USDI (Bureau of Reclamation)
   TVA

8. Potential State/University cooperation:

   University of Florida, University of California-Davis, Florida D.N.R., California Department of Agriculture, University of North Carolina, plus other States in which hydrilla has become infested.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Ted Center
   Dr. Lars Anderson

10. Funds required:

    a. Foreign exploration - $500,000 over 5 years.
    b. In-house ARS $600,000/year.

11. SY input needed:

    5.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2a
    2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Eichhornia crassipes Waterhyacinth

2. Candidate biocontrol agents (when known and appropriate):

   Neochetina eichhorniae-weevil
   N. bruchi-weevil
   Sameodes albiguttalis-moth
   Arzama densa-native moth
   Circospora spp.-Fungus (native)
   Acremonium zonatum-Fungus (native)
   Orthogalumna terebrantis-mite

3. Commodities:

   Water resources, rangelands, agricultural land.

4. Status of biocontrol research effort:

   a. Past
      1. Foreign surveys conducted 1968-1972
      2. Foreign evaluation 1968-1974
      3. Quarantine testing 1972-1977
      4. Release and establishment 1972-1977
      5. Field evaluation 1972-1984
      6. Exploration for foreign and native pathogens
      7. Testing for efficacy of white amur
      8. Testing and commercial production of native pathogens

   b. Present
      1. Studies aimed at integration, biological control information management systems so as to reduce adverse effects of chemical and mechanical control.

5. Recommended research approaches (augmentation, introduction, pathology, other)

   Augmentation of effects of biological control agents through manipulation and habitat management.

6. ARS laboratories involved (present):

   Ft. Lauderdale, Florida
   Gainesville, Florida
   Davis, California

7. Other Federal laboratories involved (present/future):

   Waterways Experiment Staion, MS

8. Potential State/University cooperation:

Florida DNR, University of Florida, California Department of Agriculture.

9. Suggested ARS contact individual(s) - (Key person):

Dr. Ted Center

10. Funds required:

$120,000

11. SY input needed:

1.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

2.4.7.2a
2.4.7.2c
2.4.7.2e

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Potamogeton pectinatus — Sago pondweed

2. Candidate biocontrol agents (when known and appropriate):

   White Amur (Triploid)
   Competitive plants (spikerushes: Eleocharis coloradoensis, E. acicularis and native soil-borne fungi.

3. Commodities:

   Irrigation and potable water, recreational water resources

4. Status of biocontrol research effort:

   a. Past (1971-1976)
      1. PL 480: Foreign (India) exploration for insects.
      2. Survey and isolation of soil-borne pathogens in California (Three isolated).
   b. Present: Laboratory testing of isolated native soil fungi in California.

5. Recommended research approaches (augmentation, introduction, pathology, other)

   a. Determine efficacy of isolated soil-borne pathogen on reproductive structures.
   b. Determine feeding behavior of Triploid white amur at different temperatures.
   c. Develop methods to manipulate and manage white Amur Triploid in canals.
   d. Discover and develop foreign insects for control.
   e. Discover and develop foreign insect control agents.
   f. Identify, isolate, and synthesize allelochemicals from Eleocharis spp.

6. ARS laboratories involved (present):

   Davis, CA

7. Other Federal laboratories involved (present/future):

   USDI (Bureau of Reclamation)

8. Potential State/University cooperation:

   University of California-Davis.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Lars Anderson

10. Funds required:

    a. Foreign exploration for insects: $300,000 over 3 years.
    b. In-house ARS sys $360,000.

11. SY input needed:

    3.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2a
    2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Myriophyllum spicatum Eurasian watermilfoil

2. Candidate biocontrol agents (when known and appropriate):

   White Amur
   Acentria nivea-moth
   Litodactylus levcogaster-beetle

3. Commodities:

   Water resources.

4. Status of biocontrol research effort:

   a. Past: PL 480 studies for BC agents in Yugoslavia, Pakistan.
      Host range tests on two native insects, Gainesville, Florida.
      Feeding preference studies with White Amur
      Manipulation of native saprophagous fungus to increase pathogenicity-Mass.
      Manipulation of native midge-Canada
      Basic studies on a native pathogen-Wisconsin.

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   a. Manipulation of the sterile triploid White Amur.
   b. Identify native pathogens, nematodes, and other organisms that attack milfoil and develop methods for their manipulation.
   c. Discover and evaluate exotic organisms that can be introduced for classical biocontrol.
   d. Evaluate native plants for their potential to exclude milfoil through competition.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   USDI (Bureau of Reclamation) - Colorado.

8. Potential State/University cooperation:

   Many universities in the infested States.

9. Suggested ARS contact individual(s) - (Key person):

   Gary R. Buckingham, Gainesville, Florida.

10. Funds required:

    $600,000

11. SY input needed:

    5.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2a
    2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism:

   Cladophora
   Pithophora
   Spirogyra
   Lyngbyra

   Common name:

   Filamentous Algae

2. Candidate biocontrol agents (when known and appropriate):

   White Amur (Triploid)
   Tilapia spp.
   fungi

3. Commodities:

   Water resources

4. Status of biocontrol research effort:

   a. Past: Use of varieties of *Tilapia* in Israel has been developed for some algae. A fungal pathogen on *Cladophora* spp. was isolated and tested by Dr. Tom Bott, Philadelphia Academy of Science.

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   a. Develop methods for manipulating triploid white amur to reduce algal biomass.
   b. Develop methods for combining *Tilapia* varieties for management of filamentous algae.
   c. Determine virulence of isolated pathogens on *Cladophora* spp.

6. ARS laboratories involved (present):

   University of California-Davis
   Stoneville, MS

7. Other Federal laboratories involved (present/future):

   None

8. Potential State/University cooperation:

   University of California-Davis
   Philadelphia Academy of Science (Dr. Thomas Bott)

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Lars Anderson

10. Funds required:

    In-house ARS: $120,000

11. SY input needed:

    1.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2a
    2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Potamogetom nodosus American pondweed

2. Candidate biocontrol agents (when known and appropriate):

   White Amur (Triploid)
   Competitive plants (spikerushes: *Eleocharis coloradoensis*, *E. aciculoris* and native soil-borne fungi.

3. Commodities:

   Irrigation and potable water, recreational water resources

4. Status of biocontrol research effort:

   a. Past (1971-1976)
      1. PL 480: Foreign (India) exploration for insects.
      2. Survey and isolation of soil-borne pathogens in California (Three isolated).

   b. Present: Laboratory testing of isolated native soil fungi in California.

5. Recommended research approaches (augmentation, introduction, pathology, other)

   a. Determine efficacy of isolated soil-borne pathogen on reproductive structures.
   b. Determine feeding behavior of Triploid white amur at different temperatures.
   c. Develop methods to manipulate and manage white Amur Triploid in canals.
   d. Discover and develop foreign insects for control.
   e. Discover and develop foreign insect control agents.
   f. Identify, isolate, and synthesize allelochemicals from *Eleocharis* spp.

6. ARS laboratories involved (present):

   Davis

7. Other Federal laboratories involved (present/future):

   USDI (Bureau of Reclamation)

8. Potential State/University cooperation:

   University of California-Davis.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Lars Anderson

10. Funds required:

    a. Foreign exploration for insects: $300,000 over 3 years.
    b. In-house ARS sys $360,000.

11. SY input needed:

    3.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2a
    2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name

   Schinus terebinthifolius — Brazilian peppertree

2. Candidate biocontrol agents (when known and appropriate):

   Seed beetles (Bruchidae): Bruchus anotatus
   Thrips
   Moths (Olethreutidae & Gelechidae)

3. Commodities:

   Water resources

4. Status of biocontrol research effort:

   a. Past: Hawaiian agencies have conducted foreign surveys and host range testing. At least three species have been released. Partial success has been achieved.

   b. Present: None at present unless Hawaii is still working on it.

5. Recommended research approaches (augmentation, introduction, pathology, other)

   a. Introduction of insects from Hawaii to U.S.
   b. Further exploration in South America.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None (possibly U. S. Park Service in future)

8. Potential State/University cooperation:

   Florida Department of Natural Resources, University of Florida, California State agencies, Hawaiian State agencies.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Ted Center

10. Funds required:

    $120,000.

11. SY input needed:

    1.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

2.4.7.2c
2.4.7.1b

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Lemna spp. Duckweeds
   Spirodela spp.

2. Candidate biocontrol agents (when known and appropriate):

   White Amur (Triploid)
   Native insects (weevils, flies, moth)

3. Commodities:

   Lakes, ponds, reservoirs, drainage canals.

4. Status of biocontrol research effort:

   a. Past: White amur and hybrid white Amur removed duckweeds in small-scale feeding trials.

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   a. Develop native insects for biocontrol (primarily in Florida).
   b. Determine stocking rate of Triploid White Amur needed for control.

6. ARS laboratories involved (Present):

   Davis, CA

7. Other Federal laboratories involved:

   None

8. Potential State/University cooperation:

   University of Florida-Gainesville, University of California-Davis.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Gary Buckingham

10. Funds required:

    $240,000.

11. SY input needed:

    2.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

2.4.7.2a
2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Typha latifolia Cattails

2. Candidate biocontrol agents (when known and appropriate):

   Manipulate nematodes, native insects, and pathogens

3. Commodities:

   Water resources; wetlands

4. Status of biocontrol research effort:

   a. Past (1971-1976): Little or no research on biological control.

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   a. Identify and evaluate native pathogens, insects, and nematodes on *Typha* sp.
   b. Develop basic knowledge of responses of *Typha* to nematodes, insects, and pathogens.

6. ARS laboratories involved (present):

   None

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation:

   University of California-Davis, University of Florida-Gainesville, Washington State University.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Lars Anderson
   Dr. Ted Center
   Dr. Richard Comes

10. Funds required:

    $240,000.

11. SY input needed:

    2.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

2.4.7.2a
2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Pistia stratiotes — Water lettuce

2. Candidate biocontrol agents (when known and appropriate):

   Episamia pecticornis-moth
   Paulinia acuminata-grasshopper
   Argentinorhynchus spp.-weevils
   Neohydronomus pulchellus-weevil
   Neochetous bruchi-weevil

3. Commodities:

   Water resources.

4. Status of biocontrol research effort:

   a. Past: Preliminary host range tests were conducted in South America on several weevils. A moth in Thailand was manipulated for biocontrol, a South American grasshopper was introduced into Africa.

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   Importation and quarantine evaluation of the Asian moth, Episamia pecticornis. The host range of this moth has been extensively tested in Thailand and it has shown promise for biocontrol.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation:

   University of Florida.

9. Suggested ARS contact individual(s) - (Key person):

   Gary R. Buckingham, Gainesville, Florida.

10. Funds required:

   $120,000

11. SY input needed:

1.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

2.4.7.2a
2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Myriophyllum aquaticum — Parrotfeather

2. Candidate biocontrol agents (when known and appropriate):

   Phytobius impressiventris-weevil
   Parenthis restitus-weevil
   Pythium spp.

3. Commodities:

   Water resources.

4. Status of biocontrol research effort:

   a. Past: Insect surveys have been made in South America and two native weevils have been studied in Florida; a native fungus, Pythium spp., has been tested in California.

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   a. Import and evaluate one or two native weevils from the Southeastern U.S. into California to control the aerial stems.
   b. Discover and evaluate exotic organisms for classical biocontrol.
   c. Evaluate native pathogens for manipulation.

6. ARS laboratories involved (present)

   Davis, California

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation:

   University of Florida.
   University of California-Davis

9. Suggested ARS contact individual(s) - (Key person):

   Dr. L. W. Anderson

10. Funds required:

    $120,000

11. SY input needed:

    1.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2a
    2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Ludwigia spp. Water primrose, primrose willow.

2. Candidate biocontrol agents (when known and appropriate):

   Virus-like organism in Carolinas. Others presently not known.

3. Commodities:

   Water resources, farmlands, rangelands.

4. Status of biocontrol research effort:

   a. Past: None - some casual observation of diseases in the Carolinas.

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   Surveys of natural enemies both foreign and domestic.
   Augmentation of native insects and diseases.
   Introduction of exotic biological control agents.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation:

   Unknown, probably many State agencies and universities.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Ted Center

10. Funds required:

    $120,000.

11. SY input needed:

    1.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2a
    2.4.7.2c
    2.4.7.1b

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Egeria densa Brazilian elodea, egeria

2. Candidate biocontrol agents (when known and appropriate):

   None known, possibly White Amur

3. Commodities:

   Water resources.

4. Status of biocontrol research effort:

   a. Past: None, possibly included in White Amur feeding trials.

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   Augmentation of natural controls via release of White Amur sterile hybrid.
   Discover and evaluate exotic insects and other arthropods potentially useful for control.
   Discover and evaluate native agents which may be amenable to manipulative approaches.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None (possibly Park Service in Everglades)

8. Potential State/University cooperation:

   University of Florida, Florida DNR, South Carolina State agencies and universities.

9. Suggested ARS contact individual(s) - (Key person):

   Gary Buckingham

10. Funds required:

    $600,000

11. SY input needed:

    5.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2a
    2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Hygrophila polysperma Miramar Weed

2. Candidate biocontrol agents (when known and appropriate):

   None yet known.

3. Commodities:

   Water resources

4. Status of biocontrol research effort:

   a. Past: None

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   Chemical biological approach involving foreign exploration and testing of candidate agents with subsequent release in U.S. Testing of White Amur for efficacy as control agent. Survey for pathogens (domestic and foreign) and test augmentation of native pathogens.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None (possibly U. S. Park Service in future)

8. Potential State/University cooperation:

   State agencies and universities in Florida, particularly DNR and UF.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Ted Center

10. Funds required:

    $600,000.

11. SY input needed:

    5.0 initially.

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Elodea canadensis — Elodea

2. Candidate biocontrol agents (when known and appropriate):

   White Amur (Triploid)
   Manipulate native insects.

3. Commodities:

   Water resources, irrigation systems

4. Status of biocontrol research effort:

   a. Past: Small-scale feeding trials with White Amur; competitive beneficial plants.

   b. Present: Competitive plant interactions (Eleocharis spp.)

5. Recommended research approaches (augmentation, introduction, pathology, other)

   a. Discover and evaluate native insect as control agents.
   b. Develop manipulative methods to enhance effectiveness of insects.
   c. Develop management strategies using Triploid White Amur in static and flowing water.

6. ARS laboratories involved (present):

   Davis

7. Other Federal laboratories involved:

   None

8. Potential State/University cooperation:

   University of California-Davis; Washington State University.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Lars Anderson
   Dr. Suzanne Batra

10. Funds required:

    $120,000.

11. SY input needed:

    1.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

2.4.7.2a
2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Phragmites communis Phragmites

2. Candidate biocontrol agents (when known and appropriate):

   None known.

3. Commodities:

   Water.

4. Status of biocontrol research effort:

   a. Past: None

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   Discover and evaluate native pathogens, nematodes, insects, and investigate means of manipulation or augment effect to provide control.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None (possibly Park Service in Everglades)

8. Potential State/University cooperation:

   University of California-Davis, Washington State University, University of Florida.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Lars Anderson

10. Funds required:

    $120,000

11. SY input needed:

    1.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2a
    2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Najas guadalupensis — Southern naiad

2. Candidate biocontrol agents (when known and appropriate):

   Possibly White Amur

3. Commodities:

   Water resources.

4. Status of biocontrol research effort:

   a. Past: Small-scale feeding trials with White Amur

   b. Present: None

5. Recommeded research approaches (augmentation, introduction, pathology, other).

   a. Manipulate the White Amur.
   b. Discover and evaluate native pathogens, nematodes, and insects that could be manipulated.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation:

   University of Florida.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. K. Steward, Ft. Lauderdale, Florida
   Dr. L. W. J. Anderson, Davis, CA

10. Funds required:

    $120,000

11. SY input needed:

    1.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2a
    2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Panicum repens Torpedograss

2. Candidate biocontrol agents (when known and appropriate):

   Exotic organisms
   Possibly White Amur (Triploid)

3. Commodities:

   Water resources.

4. Status of biocontrol research effort:

   a. Past: None

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   a. Discover and evaluate exotic organisms including insects, pathogens.
   b. Evaluate methods to manipulate growth of torpedograss to make it amenable to control using Triploid White Amur.

6. ARS laboratories involved (present):

   Ft. Lauderdale.

7. Other Federal laboratories involved (present/future:

   None

8. Potential State/University cooperation:

   University of Florida-Gainesville.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Thai Van
   Dr. Kerry Steward

10. Funds required:

    a. Foreign Exploration: $120,000.
    b. In-house ARS: $120,000

11. SY input needed:

2.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

2.4.7.2a
2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Melaleuca quinquenervia — Cajkeput, Australian punk tree

2. Candidate biocontrol agents (when known and appropriate):

   Several known from Australia but comprehensive list not yet compiled.

3. Commodities:

   Water resources, wetlands, farmlands, pasture lands.

4. Status of biocontrol research effort:

   a. Past: Some surveys have been done in Australia.

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   Introduction of Australian insects via classical biocontrol methodology.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None (possibly Park Service in Everglades)

8. Potential State/University cooperation:

   Florida DNR, University of Florida, University of Miami.

9. Suggested ARS contact individual(s) - (Key person):

   Dr. Ted Center

10. Funds required:

    C/A $50,000/year for 5 years initially to contract with Australian research agencies to survey for natural enemies.

11. SY input needed:

    1.0 initially, 2-3 SYs later.

12. Appropriate approach element(s) and problem(s) and subproblem(s):

2.4.7.2a
2.4.7.2c
2.4.7.1b

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Lythrum salicaria Purple loosestrife

2. Candidate biocontrol agents (when known and appropriate):

   Numerous European insects

3. Commodities:

   Water resources.

4. Status of biocontrol research effort:

   a. Past: Foreign surveys have been conducted in Europe by a U.S. researcher.

   b. Present: Yugoslavian researchers are conducting surveys of insects for a U.S. research program.

5. Recommeded research approaches (augmentation, introduction, pathology, other).

   a. Discover and evaluate exotic organisms for classical biocontrol.
   b. Evaluate native pathogens and insects for possible manipulation.

6. ARS laboratories involved (present)

   Beltsville, Maryland

7. Other Federal laboratories involved (present/future)

   Frederick, Maryland
   Gainesville, Florida

8. Potential State/University cooperation:

   University of Maryland

9. Suggested ARS contact individual(s) - (Key person):

   Dr. S. Batra, Beltsville, Maryland

10. Funds required:

    $120,000

11. SY input needed:

    1.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

2.4.7.2a
2.4.7.2c

Information Summary for Each Target Pest for ARS Biological Control Program

1. Pest organism: Common name:

   Ceratophyllum demersum Coontail

2. Candidate biocontrol agents (when known and appropriate):

   Unknown, possibly White Amur

3. Commodities:

   Water resources.

4. Status of biocontrol research effort:

   a. Past: None, possibly included in White Amur feeding trials.

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other)

   Augmentation via release of White Amur sterile hybrid.
   Discovery, evaluation, and introduction of exotic organisms.
   Manipulation of native organisms and augmentation of effect by habitat management.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation:

9. Suggested ARS contact individual(s) - (Key person):

   Dr. T. K. Van
   Dr. Kerry Steward

10. Funds required:

    $600,000

11. SY input needed:

    3.0

12. Appropriate approach element(s) and problem(s) and subproblem(s):

    2.4.7.2a
    2.4.7.2c

PRIORITIES SUMMARY C.

Chairman: Rodney Bovey

Team Members: Lloyd Andres, William Bruckart, Jack DeLoach, James Duke, Dean Linscott, Sara Rosenthal, and Raymond Taylorson

I. Problem Title:

Weeds in Forages, Grazing Lands, and Nonagricultural Lands

II. Problem Statement:

Weedy plant species (herbaceous and woody plants) occupy vast acreages of pasture and rangeland and non-agricultural lands. These plants limit forage and livestock production on more than 320 million acres in the United States. They cost producers over $2 billion annually, by loss of grazing, poisoning of livestock, reducing forage production and implementation of control strategies. Weeds also reduce land values, increase difficulty of handling livestock and cause failure in establishment of new forage seedings. Thousands, perhaps millions, of man-days are lost each year due to the debilitating effects of respiratory problems of ragweed pollen and skin inflammation from poison ivy or poison oak.

Although conventional weed control strategies are suitable in many situations to control weeds of ranges and pastures, biological control has great potential where economic returns from infested lands are limited, where ecological considerations prevail (e.g. near streams) where target species are resistant to herbicides or other control methods on inaccesible terrain or areas too large to treat by conventional means.

Several plant species causing losses in U.S. grazing and non-agricultural lands are listed by relative order of importance and suitability for biological control.

III. Criteria for Priorities:

Weeds were rated on the basis of economic importance and biological control potential only.

Economics: Each weed was rated by weed and biological control scientists using a combination of personal experience and information taken from questionnaires received from ARS weed scientists throughout the United States. Quantitative data were difficult to obtain for this rating.

Biological Control Potential: There are considerable differences of opinion among biological control workers in rating the biological control potential of many weed species. Some of the weeds of high economic importance were rated as having low biological control potential because of:

a. Conflicts-of-interest. Where the target weed is valued by some for its useful qualities but regarded as deleterious by others, an economic conflict of interest was considered to exist. We did not attempt to resolve these conflicts but rather rated the biological control potential of that weed accordingly lower. In instances where the target weed was a native plant an ecological conflict of interest was declared to exist, especially if the target weed is a major ecological dominant (e.g. mesquite, sagebrush). The concern expressed by ecologists and conservation people is based on several points. Such ecological problems are often the result of poor land management. Although the introduction of natural enemies may reduce weed abundance, it is questionable whether the grazing area would be improved because of reinfestation of the same or other weeds without proper management. There also is concern that exotic natural enemies could reduce the target weed to such an extent as to cause ecological problems. There is little or no evidence that this has happened but study is needed. Because of the ecological conflict concern, most native plants targeted for biological control were rated low. Considering the economic damage caused by some of our native weeds, this conflict needs to be resolved and should receive high priority.

b. Relatedness to crops, native plants, and endangered species. Any target weed with close economic or ecological relatives was rated low to medium on biological control potential. The value of native plants - especially endangered species - and their susceptibility to attack by introduced natural enemies must be resolved. This potential conflict threatens the use of introduced organisms on many major weeds.

c. Availability of agents. If there was little information on the availability of natural enemies, target plants were rated lower, although this obviously must be considered further.

Other factors to consider in rating biological control potential of weeds but were not considered in this report were: 1) degree of control desired, 2) susceptibility to biological control, 3) or preferred biological control approach. Regarding the latter, the augmentation of using natural enemies holds some biological control potential, but it will be limited to areas where the economic return can be justified.

IV. List of Priorities:

Species of National Importance:

Cardaria draba (L.) Desv.	Hoary cress
Carduus pycnocephalus L.	Italian thistle
Carduus tenuiflorus Curt.	Slenderflower thistle
Centaurea calcitrapa L.	Purple starthistle
Centaurea diffusa Lam.	Diffuse knapweed

Centaurea maculosa Lam.	Spotted knapweed
Centaurea repens L.	Russian knapweed
Centaurea solstitialis L.	Yellow starthistle
Chondrilla juncea L.	Rush skeletonweed
Conium maculatum L.	Poison hemlock
Cytisus monspessulanus L.	French broom
Cytisus scoparius (L.) Link	Scotch broom
Gutierrezia spp. 1/	Snakeweed
Halogeton glomeratus (M. Bieb.) C.A.Mey.	Halogeton
Hieracium aurantiacum L.	Orange hawkweed
Isatis tinctoria L.	Dyers woad
Larrea tridentata (D.C.) Coville 1/	Creosotebush
Lepidium latifolium L.	Perennial pepperweed
Lythrum salicaria L.	Purple loosestrife
Rhus spp. 1/	Poison ivy poison oak
Salsola iberica Sennen & Pau	Russian thistle
Salsola paulsenii Litv.	Barbwire Russian thistle
Sonchus arvensis L.	Perennial sowthistle
Tamarix pentandra Pall, *T. gallica* L., *Tamarix parviflora* DC.	Saltcedars

Other Weeds of Importance:

Euphorbia esula L. (low to medium rating due to heterogenous nature)	Leafy spurge
Cirsium arvense (L.) Scop.	Canada thistle

(low to medium rating due to poor success with previous biocontrol research and conflicts of interests)

Carduus acanthoides L.	Plumeless thistle
Carduus nutans L.	Musk thistle

Species of Regional Importance:

Ageratina adenophora	
Ageratina riparia	
Melaleuca quinquenervia (Can.) S.T. Blake	Cajeput tree
Passiflora mollissima	Banana poka
Pluchea odorata	Arroweed
Ulex europaeus L.	Gorse

1/Native Species

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cardaria draba (L.) Desv. — hoary cress

2. Candidate biocontrol agents (when known and appropriate)

   very promising agents known in Poland

3. Commodities

   pastures, cropland

4. Status of biocontrol research effort:

   a. Past: extensive exploration in Poland for natural enemies, prob. info. on pathogens

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

   Beltsville, Stoneville, Albany

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   S. W. T. Batra; C. Turner;

10. Funds required

    For initial literature and field surveys - $60,000

11. SY input needed

    0.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Pest organism	Common name
Carduus pycnocephalus L.	Italian thistle
Carduus tenuiflorus Curt.	slenderflower thistle

2. Candidate biocontrol agents (when known and appropriate)

Rhinocyllus conicus
Puccinia carduorum
P. cardui pycnocephali
Aceria spp.

3. Commodities

ranges, pastures, roadsides

4. Status of biocontrol research effort:

a. Past: Pathogens collected in Eurasia stored at PDRL; some brief tests made with *Rhinocyllus*

b. Present: Pathogen (*P. carduorum*) studies at CDFA and compared at PDRL with *P. carduorum* from Turkey. Collection of pathogens from Eurasia continues.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Limited potential for manipulation of biocontrol agent means the classical approach is most desirable. Potential for finding pathogens/insects is good. Possible conflict of interest with *Cersium scolymus* (artichoke).

6. ARS laboratories involved (present)

Plant Disease Research Lab, Frederick;
Albany, California
Rome, Italy

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

CA Dept. Food, Agr. Sacramento, CA
Oregon

9. Suggested ARS contact individual(s) - (Key person)

W. Bruckart
S. S. Rosenthal

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Pest organism	Common name
Centaurea calcitrapa L.	purple starthistle
C. solstitialis L.	yellow starthistle

2. Candidate biocontrol agents (when known and appropriate)

Insects: *Bangasternus orientalis*
Apion alliariae
Cyphocleonus morbillosus
Aceria spp.
Eusteropus villosus
Urophora sirunasenci

Pathogens: *Puccinia jaceae*
P. centaureae
P. calitrappe
P. ourmiahensis

3. Commodities

4. Status of biocontrol research effort:

a. Past: *Urophora sirunasena* released without establishment 1972. Different ecotype to be released in 1984.

b. Present: Study of other insects in Italy and Greece; survey of Turkey; study of *P. jaceae* or *C. solstitialis* underway.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Introduction
Pathology

6. ARS laboratories involved (present)

Albany, California
Rome, Italy
Plant Disease Res Lab, Frederick, Maryland

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

California; Idaho; Montana; Washington

9. Suggested ARS contact individual(s) - (Key person)

D. M. Maddox; S. S. Rosenthal; S. Clement; W. Bruckart

10. Funds required

Foreign studies - $240,000
Domestic quarantine - $120,000

11. SY input needed

Foreign studies - 2.0 SY
Domestic studies - 1.0 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Pest organism	Common name
Centaurea diffusa Lam.	diffuse knapweed
C. maculosa Lam.	spotted knapweed

2. Candidate biocontrol agents (when known and appropriate)

Insects: *Urophora affinis*
U. quadrifasciata
Sphenaptera ingoslauica
Pelochrista
Z. medullana
Bangasternus provincialis
Larinus minutus
Pterolonche inspersa

Pathogens: *Puccinea jaceae*
P. centaureae

3. Commodities

rangelands; pastures; roadsides; waste places

4. Status of biocontrol research effort:

a. Past: Two seed nead flies (*Urophora* spp.) and crown borer (*Splenaptera*) are now in USA.

b. Present: Monitoring of these insects in USA; 1984 release of *Pelochrista* planned; study of other insects continuing in Europe and California. Evaluation of pathogens in Canada.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Introduction; pathology

6. ARS laboratories involved (present)

Albany California
Rome, Italy

7. Other Federal laboratories involved (present/future)

Frederick, Maryland

8. Potential State/University cooperation

Washington; Oregon; Idaho; Montana
also Canada (Watson, Harris)

9. Suggested ARS contact individual(s) - (Key person)

S. S. Rosenthal; P. Dunn; Bruckart (future)

10. Funds required

Foreign testing - $120,000
Domestic quarantine testing - $75,000

11. SY input needed

Foreign - 1.0 SY
Domestic quarantine - 0.6 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Centaurea repens L. — Russian knapweed

2. Candidate biocontrol agents (when known and appropriate)

Nematode: *Paranguina picridis*
Mite: *Aceria acroatilon*
Disease: *Puccinia acroptili*
Insects: *Dasyrenra* sp.
Urophora maura
U. kasochstanica
U. harinus
U. bardus
L. jacear
Aulacida acroptilonica

3. Commodities

4. Status of biocontrol research effort:

a. Past: *Paranguina picridis* released in Montana 1983; USSR studies of natural enemies

b. Present: Survey of Turkey of new natural enemies and for *Aceria acroptilon*; already used for biocontrol in USSR

5. Recommended research approaches (augmentation, introduction, pathology, other).

Introduction, pathology

6. ARS laboratories involved (present)

Albany, California

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

Montana

9. Suggested ARS contact individual(s) - (Key person)

S. S. Rosenthal

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Chondrilla juncea L. — rush skeletonweed

2. Candidate biocontrol agents (when known and appropriate)

   CSIRO, Australia, has compiled list of potential control agents

3. Commodities

   grain fields; roadsides

4. Status of biocontrol research effort:

   a. Past: *Puccinia chondrillius* releases in 1978 in California, Oregon, Washington, and Idaho along with insects.
      Aceria chondrillae, *Cystiphora schmidti* released 1970's in California, Oregon, and Washington.

   b. Present: Hasan (CSIRO, France) continues to search for pathogens against other forms of weeds.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction, pathology

6. ARS laboratories involved (present)

   Plant Disease Res Lab, Frederick, Maryland (past)
   Biological Control of Weeds Unit, Albany, California

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   California Dept Food/Agr; Idaho Dept Agr; also Washington & Oregon

9. Suggested ARS contact individual(s) - (Key person)

   Bruckart (pathology)
   Andres (entomology) Albany, California

10. Funds required

    To obtain and screen added agents from Australia - $24,000

11. SY input needed

    0.2

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Conium maculatum — poison hemlock

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   pastures; parks, moist sites

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Albany, California

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Goeden, Riverside (potential good)

9. Suggested ARS contact individual(s) - (Key person)

   Turner

10. Funds required

    Initial literature and foreign surveys - $60,000

11. SY input needed

    0.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Pest organism	Common name
Cytisus scoparius (L.) Link	scotch broom
C. monspessulanus L.	French broom

2. Candidate biocontrol agents (when known and appropriate)

Numerous natural enemies known in England and Europe on *C. scoparius*; little known on *C. monspessulanue*.

3. Commodities

forests, pastures, meadows

4. Status of biocontrol research effort:

   a. Past: Released *Apion fuscirostre* (seed weevil) and *Leucoptera spartifoliella* twig miner in early 1960's in California.

   b. Present: Limited evaluation studies of releases only.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Inoculative. Several insects are good candidates.

6. ARS laboratories involved (present)

Albany, California

7. Other Federal laboratories involved (present/future)

None

8. Potential State/University cooperation

USDA/California, Oregon, Washington

9. Suggested ARS contact individual(s) - (Key person)

C. Turner, Albany, California
Andres, Albany, California

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Gutierrezia sarothrae — snakeweed

2. Candidate biocontrol agents (when known and appropriate)

   Heilipodus ventralis
   Carmenta hoematica
   Dactylozodes spp.
   Agrilus leacostictus
   Acptilia spp.

3. Commodities

   rangelands

4. Status of biocontrol research effort:

   a. Past: Extensive exploration made in Argentina

   b. Present: Two species being tested (in quarantine)

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction

6. ARS laboratories involved (present)

   Temple, Texas

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   C. J. DeLoach

10. Funds required

    $240,000

11. SY input needed

    2 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Conflict of interest and question of native weed control must be resolved (high priority).

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Halogeton glomeratus (M. Bieb) C. A. Mey. — halogeton

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   rangeland

4. Status of biocontrol research effort:

   a. Past:
   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Hieracium aurantiacum L. — orange hawkweed

2. Candidate biocontrol agents (when known and appropriate)

   Good candidate insects and pathogens found in Europe.

3. Commodities

   fields, meadows, roadsides

4. Status of biocontrol research effort:

   a. Past:

   b. Present: Europeans may be searching for natural enemies.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction, pathology
   Innoculative and innundative

6. ARS laboratories involved (present)

   Beltsville, Maryland (S. W. T. Batra)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   S. W. T. Batra, Beltsville, Maryland

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Isatis tinctoria L. — dyers woad

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   small grains, pastures; forages; rangelands

4. Status of biocontrol research effort:

   a. Past: Surveys in Mediterranean area (USDA, P. Dunn, Rome); Poland (PL-480, Lipa)

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction, pathology. Weed naturalized to U.S. from Southeast Europe and West Asia and amenable to control by introduced natural enemies.

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   USDA/Utah, Idaho, California

9. Suggested ARS contact individual(s) - (Key person)

   Andres (Albany, California); Dunn (Rome)

10. Funds required

    Additional literature and field surveys needed. Est. $60,000 for control effort.

11. SY input needed

    0.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Larrea tridentata (D.C.O Coville) — creosotebush

2. Candidate biocontrol agents (when known and appropriate)

   Several root and stem bearing insects; scale insects found in Argentina

3. Commodities

   rangelands

4. Status of biocontrol research effort:

   a. Past: Explorations for natural enemies made in Argentina.

   b. Present: Exploration continuing, attempts to resolve conflict of interest in progress.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction

6. ARS laboratories involved (present)

   Temple, Texas

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   DeLoach

10. Funds required

    $60,000

11. SY input needed

    0.5 SY

(If conflicts resolved, 5 SY and $500,000 to test and introduce insects)

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Conflicts related to controlling native plants must be resolved.

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Lepidium latifolium L. — perennial pepperweed

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   cropland; range; pastures; waste places

4. Status of biocontrol research effort:

   a. Past:
   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction. Naturalized to U.S. from Turkey, Lebanon; all natural enemies should be considered (e.g. insects, pathogens, etc.)

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

    For initial literature and field surveys - est. $60,000

11. SY input needed

    0.5 SY to evaluate biological control possibility

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Lythrum salicaria L — purple loosestrife

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   wet lands (natural resources)

4. Status of biocontrol research effort:

   a. Past: Limited surveys of natural enemies - Italy, Yugoslavia

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

   pathogens, insects collected in Eurasia for evaluation/and release

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   good-also Canada

9. Suggested ARS contact individual(s) - (Key person)

   Batra, Bruckart

10. Funds required

    Added foreign surveys - $120,000

11. SY input needed

    Foreign - 0.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism

Pest organism	Common name
Rhus radicans	poison ivy
Rhus toxicodendron	poison oak

2. Candidate biocontrol agents (when known and appropriate)

   Some promising control agents known in Japan (twig borer, foliage feeder)

3. Commodities

   fields, pastures, woods, and waste places.

4. Status of biocontrol research effort:

   a. Past: University of California, Berkeley sponsored survey for natural enemies in Japan.

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation, introduction, pathology

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

   Beltsville; Temple

8. Potential State/University cooperation

   VPI&SU

9. Suggested ARS contact individual(s) - (Key person)

   S. W. T. Batra, Beltsville, Maryland
   C. J. DeLoach, Temple, Texas

10. Funds required

    $60,000

11. SY input needed

    0.5 SY for initial surveys, resolve conflicts.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Minor conflicts of interest and questions of controlling native weeds must be resolved.

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Pest organism	Common name
Salsola paulsenii Litv.	barbwire Russian thistle
S. iberica	Russian thistle

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

disturbed areas; rangelands; abandoned fields

4. Status of biocontrol research effort:

a. Past: Exploration in Russia, Pakistan. Two insects released in U.S. and established.

b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

Introduction

6. ARS laboratories involved (present)

Albany, California

7. Other Federal laboratories involved (present/future)

Temple, Texas

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

Pemberton (Albany); DeLoach

10. Funds required

$60,000 for exploration in China

11. SY input needed

0.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Sonchus arvensis — perennial sowthistle

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   pastures; forage crops; waste places

4. Status of biocontrol research effort:

   a. Past: None

   b. Present: Studies in Canada

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   Batra, Bruckart

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.071.b
    2.4.09.1.c
    2.4.09.1.d

(Possible cooperation with Canada (Watson, Harris).

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Tamarix pentandra — saltcedar

2. Candidate biocontrol agents (when known and appropriate)
   Steragpis squanosa (buprestid)
   Agdistis spp. (moth)
   Semiothisa aestimaris (moth)
   Ornataivalva spp. (moth)
   Coniatus spp. (beetle)
   Cryptocephalus fulgurans (beetle)
   Hytoglacitis benenotala (noctuidae)

3. Commodities

   ranges, pastures in flood plains of western streams

4. Status of biocontrol research effort:

   a. Past: Exploration in Israel and Pakistan - many promising control agents

   b. Present: None - must resolve economic conflicts of interest

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction

6. ARS laboratories involved (present)

   Temple, Texas

7. Other Federal laboratories involved (present/future)

   Temple, Texas
   Albany, California

8. Potential State/University cooperation

   Southwestern U.S. state universities

9. Suggested ARS contact individual(s) - (Key person)

   C. J. DeLoach, R. Pemberton

10. Funds required*

    $60,000 (+ $600,000)

11. SY input needed*

0.5 SY (+ 5 SY)

* To assemble information to resolve conflicts of interest, then 5 SY to introduce, test, and establish natural enemies.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Euphorbia esula L. — leafy spurge

2. Candidate biocontrol agents (when known and appropriate)

   Insects: *Aphthora* (flea beetle)
   Bayeria (gall midge)
   Lobesia (shoot tip moth)
   Oberea (shoot root borer)
   Oncochila simplex
   Symyra dentosa
   Dicranocephalus spp.

   Pathogens: *Melampsora* spp.
   Uromyces scutellatus
   Alternaria spp.

3. Commodities

   pastures; rangelands

4. Status of biocontrol research effort:

   a. Past:

   b. Present: one species of *Melampsora* being studied; collections planned.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction, pathology

6. ARS laboratories involved (present)

   Albany, California
   Plant Disease Res. Lab, Frederick, Maryland

7. Other Federal laboratories involved (present/future)

   BCWLE, Rome

8. Potential State/University cooperation

   Montana State University

9. Suggested ARS contact individual(s) - (Key person)

   R. W. Pemberton
   W. Bruckart (pathology)

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cirsium arvense — Canada thistle

2. Candidate biocontrol agents (when known and appropriate)

   The lace bug Tingis ampliata and Chrysomelid Flema cyanella are in screening tests. Established agents include the stem mining weevil Ceutorhynchus litura and the stem gall fly Urophora cardui but no apparent significant reduction of Canada thistle.

3. Commodities

   Cropland, pasture, rangeland

4. Status of biocontrol research effort:

   a. Past: Ceutorhynchus litura and Urophora cardui released in Canada.

   b. Present: Tingis ampliate and Lema cyanella being screened, other insects being searched for including the native pathogen P. punctiventris.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Further investigation of rust as a biocontrol agent.

6. ARS laboratories involved (present)

   Albany, California; Beltsville, Maryland; Rome, Italy

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Montana State Univ., Washington State Univ., Univ. of Idaho, Oregon State Univ., Wyoming State Dept. of Agric.

9. Suggested ARS contact individual(s) - (Key person)

   Sara Rosenthal, Lloyd Andres, Suzanne Batra

10. Funds required

    $150,000

11. SY input needed

1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Carduus acanthoides L. — plumeless thistle

2. Candidate biocontrol agents (when known and appropriate)

Puccinia calcitrappi
Insects: Rhinocyllus conicus
Trichosirocanlus lorridus

3. Commodities

pastures, ranges, roadsides, waste places

4. Status of biocontrol research effort:

a. Past: no pathology; weevil releases against musk thistle affect C. acanthoides

b. Present: plans for exploration for pathogens

5. Recommended research approaches (augmentation, introduction, pathology, other).

Introduction; pathology

Classical approach with exotic pathogens or insects recommended. Significance of potential for hybridization of C. acanthoides with C. nutans (muck thistle) needs to be known.

6. ARS laboratories involved (present)

possibly

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

Kok - VA Polytechnic Inst. & State U, insects
Baudoin also at VPI (pathology)

9. Suggested ARS contact individual(s) - (Key person)

Bruckart - pathology - Frederick
Batra - entomology - Beltsville

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Carduus nutans — Musk thistle

2. Candidate biocontrol agents (when known and appropriate)

   Ceutorhynchus trimaculatus and Cheilosia corydon under study.

3. Commodities

   pasture and rangeland

4. Status of biocontrol research effort:

   a. Past: Rhinocyllus conicus established and works well in some sites on seed. Trichosirocalus (Ceutorrhynchiclus) horridus established in several states but impact unknown.

   b. Present: Ceutorhynchus trimaculatus and Cheilosia corydon under study.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Rome, Italy; Albany, California; Beltsville, Maryland.

7. Other Federal laboratories involved (present/future)

   Frederick, Maryland (rust)

8. Potential State/University cooperation

   Univ. of Nebraska, Montana State Univ., Univ. of Idaho, Washington State Univ., and Univ. of Wyoming

9. Suggested ARS contact individual(s) - (Key person)

   S. Rosenthal and L. Andres, Albany, California
   B. Bruckart, Frederick, Maryland
   S. Batra, Beltsville, Maryland
   P. Dunn, Rome, Italy

10. Funds required

    $300,000

11. SY input needed

    2 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.07.1.b
2.4.09.1.c
2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Melaleuca quinquenerva — cajeput tree

2. Candidate biocontrol agents (when known and appropriate)

   Several good from Australia

3. Commodities

   everglades

4. Status of biocontrol research effort:

   a. Past: Some exploration for natural enemies.

   b. Present: Little or none - need to resolve conflict of interest.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction

6. ARS laboratories involved (present)

   Ft. Lauderdale, Florida

7. Other Federal laboratories involved (present/future)

   Gainesville, Florida
   Albany, California

8. Potential State/University cooperation

   University of Florida

9. Suggested ARS contact individual(s) - (Key person)

   Ted Center, C. Turner

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Passiflora mollisima — banana poka

2. Candidate biocontrol agents (when known and appropriate)

   Pyrausta perelegona plus others

3. Commodities

   forest

4. Status of biocontrol research effort:

   a. Past: Pemberton survey of *Passiflora* in South America for natural enemies. Trujillo from Hawaii explored for pathogens.

   b. Present: Trujillo has research proposal submitted (to Hawaii?).

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction, pathology

6. ARS laboratories involved (present)

   Hawaii

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   University of Hawaii (Trujillo)

9. Suggested ARS contact individual(s) - (Key person)

   L. Andres & R. W. Pemberton

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Note: *P. mollisima* vines over native trees in Hawaiian forests. Biological control is the only hope to control this weed.

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Pluchea odorata — arrowweed

2. Candidate biocontrol agents (when known and appropriate)

   Probably exist in southwestern U.S.

3. Commodities

   Pastures - Hawaii
   Waste lands, newly cleared agricultural land

4. Status of biocontrol research effort:

   a. Past: Hawaiian surveys at West Indies and Central America. Two insects introduced. Little or no control reported.

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction
   Native to tropical America

6. ARS laboratories involved (present)

   Hawaii

7. Other Federal laboratories involved (present/future)

   Stoneville, Mississippi
   Gainesville, Florida

8. Potential State/University cooperation

   University of Hawaii

9. Suggested ARS contact individual(s) - (Key person)

   C. Turner (Albany)

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Ulex europaeus — gorse

2. Candidate biocontrol agents (when known and appropriate)

   Apion ulicis - seed weevil has been released; potential agents include the moth *Agonoptorik uticetella* and the tingid *Dictyonota strichnocera*

3. Commodities

   Pasture

4. Status of biocontrol research effort:

   a. Past: Release of seed weevil which effectively destroys seed

   b. Present: Research on potential agents being conducted in New Zealand.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   USDA/California, Oregon

9. Suggested ARS contact individual(s) - (Key person)

   D. M. Maddox (Albany, California)

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Ageratina adenophora — None known

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

4. Status of biocontrol research effort:

   a. Past:
   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

   Hawaii

8. Potential State/University cooperation

   University of Hawaii

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.07.1.b
    2.4.09.1.c
    2.4.09.1.d

Priorities Summary D.1

Chairman: Dale E. Meyerdirk

Team Members: Richard Dysart, George Gassner, Matthew Greenstone, Keith Hopper, Richard Humber, Gary Moorehead, and Jack Witz

I. Problem Title:

Crop Insects: Tree Crops

II. Problem Statement:

Tree crops including fruits and nuts constitute a total of 2.8 million acres of agricultural land mass in the United States with a production value above 4.5 billion dollars in 1981. Each tree crop has its own specific pest complex which can differ from one geographical area to another. Numerous phytophagous insects of two crops are presently under biological control effectively being regulated by their natural enemies. Tree crops are more amendable to habitat manipulation for conservation and augmentation of parasitioids, predators and pathogens and historically have had more biological control successes than other agricultural crop systems. Numerous primary pests continue to be of economic importance to tree crops requiring pesticide applications which can cause secondary pest outbreaks by disrupting the existing natural enemy complex. These primary pests need to be brought under biological control.

III. Criteria for Priorities:

a. Economic importance of pest.
b. Is pest of national, regional, or local importance.
c. Effectiveness of current biological control techniques.
d. Potential for control of biological agents.
e. Availability of biocontrol agents.

IV. List of Priorities:

	Scientific name	Common name	Code
1.	Cydia pomonella (L.)	codling moth	221
2.	Ceratitis capitata (Wiedeemann)	Mediterranean fruit fly	90
3.	Panonychus citri (McGegor)	citrus red mite	8
4.	Tetranychus urticae Koch	two spotted spider mite	9
5.	Popillia japonica Newman	Japanese beetle	60
6.	Aphis gossypii Glover	cotton aphid	119
7.	Empoasca spp.	leafhoppers	142
8.	Rhagoletis spp.	fruit maggots	93, 351, 352
9.	Amyelois transitella (Walker)	navel orangeworm	230
10.	Quadraspidiotus perniciosus (Comstock)	San Jose scale	154
11.	Psylla pyricola Foerster	pear psylla	167
12.	Aphis citricola (Van der Goot)	spirea aphid	120
13.	Myzus persicae (Sulzer)	green peach aphid	131
14.	Hyphantria cunea (Drury)	fall webworm	180
15.	Monellia costalis (Fitch)	blackmargined aphid	127
16.	Synanthedon exitiosa (Say)	peachtree borer	256
17.	Argyrotaenia velutinana (Walker)	redbanded leafroller	265
18.	Phylloxera devastatrix Pergande	pecan phylloxera	161
19.	Circulifer tenellus (Baker)	beet leafhopper	139
20.	Pseudaulacaspis pentagona (Targi.-Tozz.)	white peach scale	153
21.	Eutetranychus banksi (McGregor)	Texas citrus mite	7
22.	Olethreutes spp.	Olethreutes leafrollers	222
23.	Curculio caryae (Horn)	pecan weevil	38
24.	Phyllocoptruta oleivora (Ashmead)	citrus rust mite	2
25.	Archips argyrospilus (Walker)	fruittree leafroller	263
26.	Alsophila pometaria (Harris)	fall cankerworm	188
27.	Lygus spp.	plant bugs	100
28.	Conotrachelus nenuphar (Herbst)	plum curculio	35
29.	Anarsia lineatella Zeller	peach twig borer	184
30.	Anastrepha suspensa (Loew)	Caribbean fruit fly	89
31.	Dacus dorsalis Hendel	Oriental fruit fly	92

Tree Crops

Tree Crop Insects Under Biological Control

No.	Species	BC Status
164	*Pseudococcus comstocki*	Complete
149	*Lepidosaphes beckii*	Complete
150	*Lepidosaphes gloveri*	Partially complete
146	*Saissetia oleas*	Complete
122	*Chromaphis juglandicola*	Complete
163	*Planococceis citri*	Complete
110	*Aleurocanthus wolgumi*	Complete
113	*Dialeurodes citri*	Partial
123	*Eriosoma* spp.	1 species complete
144	*Coccus hesperidum*	Complete

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cydia pomonella (L.) — Codling moth

2. Candidate biocontrol agents (when known and appropriate)

   Braconid from Central Asia named *Microdus rufapis* imported in 1976 and fungal pathogens: *Beauveria bassiana* and *Paecilomyces* sp.; and bacterium: *Bacillus thuringiensis*.

3. Commodities

   Apples, pears, quince, walnuts.

4. Status of biocontrol research effort:

   a. Past: Extensive biological control efforts 1904, 1905, 1935, 1947; Canada (1942-46). Attempts have resulted in failure to date since 1947. *Ascogaster* spp. and *Cryptus* sp. have been introduced but did not become established.

   b. Present: No existing program.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introductions

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   Stan Hoyt - Washington

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Ceratitis capitata Wiedemann — Mediterranean Fruit Fly

2. Candidate biocontrol agents (when known and appropriate)

   Possibly pathogens: Entomophthorales and *Beauveria* sp. plus parasitoids.

3. Commodities

   250 fruits and vegetables

4. Status of biocontrol research effort:

   a. Past: The following have been introduced and established:
      Bioateres oophilus
      B. longicaudatus
      B. tryoni

   b. Present: ARS Hawaii -
      Texas A&M University - Exploration for natural enemies

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introductions

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

   Dr. Frank Gilstrap
   Texas A&M University
   College Station, TX

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

   Panonychus citri (McGregor) | Citrus red mite

2. Candidate biocontrol agents (when known and appropriate)

   Predaceous mites

3. Commodities

   Citrus

4. Status of biocontrol research effort:

   a. Past: Importation of phytoseid mites

   b. Present: Use of phytoseiid mites and viruses.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation, introduction, pathology

6. ARS laboratories involved (present)

   Texas and Florida

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   University of California at Riverside and Berkeley

9. Suggested ARS contact individual(s) - (Key person)

   W. Hart
   A. Selhime

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   <u>Tetranychus</u> <u>urticae</u> Koch — Two spotted spider mite

2. Candidate biocontrol agents (when known and appropriate)

   Phytoseid mites

3. Commodities

   Deciduous fruit trees, some citrus

4. Status of biocontrol research effort:

   a. Past: Good control established in parts of California, some pesticide resistant strains selected and released in fruit orchards.

   b. Present: Increased selections for pesticides, more dissemination and studies on dispersal.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation of phytoseid populations, introduction of pesticide resistant strains adapted to local pest management environment, possible pathogens (virus and fungi).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Marjorie Hoy
   University of California, Berkeley

   Ali Niazes
   Department of Entomology
   Oregon State University

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Aphis gossypii Glover — Cotton aphid

2. Candidate biocontrol agents (when known and appropriate)

   Lysophlebus sp. from Japan. Aphid parasites from Taiwan. Six species of Entomophthoraleans and *Verticillium lecanii*.

3. Commodities

   Citrus, multiple vegetables

4. Status of biocontrol research effort:

   a. Past: Minimal biocontrol efforts.

   b. Present: New proposals being submitted.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introductions and augmentation.

6. ARS laboratories involved (present)

   Boyden Lab, Riverside, CA

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   University of California, Riverside

9. Suggested ARS contact individual(s) - (Key person)

   Dale E. Meyerdirk

10. Funds required

    $200,000 for 4 years.

11. SY input needed

    1.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Empoasca spp. — Leafhoppers

2. Candidate biocontrol agents (when known and appropriate)

   Egg parasitoids: Anagrus sp., Anaphes sp. Polynema sp.; Pipunculids, etc.; Erynia radicans (Entomophthorales); Hirsutella guyana and Verticillium sp.

3. Commodities

   Citrus

4. Status of biocontrol research effort:

   a. Past: Some introductions in past.

   b. Present: Biocontrol of potato leafhoppers.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introductions and augmentation.

6. ARS laboratories involved (present)

   Beneficial Insects Research Laboratory, Newark, DE

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   Bob Hendrickson
   Beneficial Insects Research Laboratory
   Newark, DE

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Amyelois transitella (Walker) — Navel Orangeworm

2. Candidate biocontrol agents (when known and appropriate)

   Bethylid wasps and Fungi: *Beauveria lassiana* and possibly entomophthoraleans.

3. Commodities

   Almonds

4. Status of biocontrol research effort:

   a. Past:

   b. Present: Introduced Bethylids

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation - Timing of releases and spray programs.
   Introduction -
   Pathology

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   University of California at Riverside
   Dr. Fred Legner

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Circulifer tenellus (Baker) — Beet leafhopper

2. Candidate biocontrol agents (when known and appropriate)

   Pipunculidae
   Dyrinidae — Nymph and adult parasitoids

   Mymaridae
   Trichogrammatidae — Egg parasitoids

3. Commodities

   Citrus, tomatoes, peppers, sugarbeets, melons, beans, cucurbits, ornamentals

4. Status of biocontrol research effort:

   a. Past: Some introductions made in late 1950's from the Mediterranean Region. Beet leafhopper now believed to be indigenous to Afghanistan.

   b. Present: No formal program.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction and augmentation.

6. ARS laboratories involved (present)

   Boyden Fruit and Vegetable Insects Research Laboratory
   Riverside, CA

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   University of California at Riverside

9. Suggested ARS contact individual(s) - (Key person)

   Dale E. Meyerdirk
   Boyden Fruit and Vegetable Insects Reserach Lab
   Riverside, CA

10. Funds required

$130,000/3 years

11. SY input needed

1.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.09.1.a

PRIORITIES SUMMARY D.1.2

Chairman: Gerry Sutter

Team Members: John Andaloro, Tom Ashley, William Day, John Drea, John Henry, Edgar King, Les Lewis, Joe Lewis, Ben Puttler, Robert Stinner, and James Vaughn

I. Problem Title:

Insect pests of graminaceous and forage crops.

II. Problem Statement:

The following insects were selected from the master list and evaluated relative to pest status and potential for biological control. These insects or insect complexes were given numerical ratings for economic importance, need for biocontrol and potential for biocontrol. The numerical scores assigned are not intended to be used for ranking. The numerical ratings are merely a consensus of the committee with respect to each of the criteria.

III. Criteria for Priorities:

a. Economic importance of pest.

b. Need for biological control.

c. Potential for control by biological control agents.

IV. List of Priorities:

1 - Low 2 - Medium 3 - High

	Economic Importance	Need for Biocontrol	Potential for Biocontrol
corn rootworms	3	3	2
corn earworm	3	3	2
European corn borer	3	2	2
grasshoppers	3	3	2
clover root curculio	2	2	2
plant bugs (Lygus, Adelphoconis)	2	2	2
fall armyworm	3	2	2
armyworm	1	1	2
black cutworm	1	2	1
army cutworm	2	2	1
SW corn borer	2	2	2
potato leafhopper	3	2	1
alfalfa weevil complex (Western)	2	2	2
green bug	2	2	1
sugar cane borer	2	1	2
sorghum midge	1	2	2
Hessian Fly	1	2	2
corn leaf aphid	1	1	1
rice water weevil	2	2	1
clover head weevil	2	1	2
alfalfa looper	1	1	1
range caterpillar	1	2	2

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Diabrotica virgifera virgifera LeConte — Western corn rootworm (23)

2. Candidate biocontrol agents (when known and appropriate)

   Predators: *Pterostichus lucublandus* Carabids, *Androlaelaps* sp. Mite, *Lasius neoniger* Ant, Ant sp., *Stratiolaelaps* sp. Mite

   Parasites: *Celatoria diabroticae* Tachinid, *Heterorhabditis heliothidis* Nematode, *Heterorhabditis bacterophora* Nematode, *Filipjevimermis leipsandra* Nematode, *Steinernema feltiae* Nematode

3. Commodities

   Corn

4. Status of biocontrol research effort:

   a. Past: Limited. Minimal survey of Cornbelt. Several explorations to Peru and Mexico.

   b. Present: Microsporidia (Gregariues); nematodes.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Develop expertise in handling available biological control agents. Conduct basic laboratory and microplot research to establish environment parameters, etc., which are prerequisites to pilot field programs.

6. ARS laboratories involved (present)

   Northern Grain Insects Research Laboratory, Brookings. SD
   Beneficial Insect Introduction Laboratory, Beltsville, MD

7. Other Federal laboratories involved (present/future)

   Columbia, MO; Charleston, SC

8. Potential State/University cooperation

   Rutgers

9. Suggested ARS contact individual(s) - (Key person)

   G. R. Sutter, Brookings, SD

10. Funds required

    $120,000

11. SY input needed

1 SY based at NGIRL to initiate disease and parasite exploration and efficacy.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Diabrotica virgifera zeae Krysan and Smith — Mexican corn rootworm (311)

2. Candidate biocontrol agents (when known and appropriate)

   Predators: Chauliognathus sp. Cantharidae

   Parasites: Beauvaria sp. Fungus

3. Commodities

   Corn

4. Status of biocontrol research effort:

   a. Past: Limited. Minimal survey of Cornbelt. Several explorations to Peru and Mexico.

   b. Present: Microsporidia (Gregariues); nematodes

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Develop expertise in handling available biological control agents. Conduct basic laboratory and microplot research to establish environment parameters, etc., which are prerequisites to pilot field programs.

6. ARS laboratories involved (present)

   Northern Grain Insects Research Laboratory, Brookings, SD
   Beneficial Insect Introduction Research Laboratory, Beltsville, MD

7. Other Federal laboratories involved (present/future)

   Columbia, MO; Charleston, SC

8. Potential State/University cooperation

   Rutgers

9. Suggested ARS contact individual(s) - (Key person)

   G. R. Sutter, Brookings, SD

10. Funds required

   $120,000

11. SY input needed

1 SY based at NGIRL to initiate disease and parasite exploration and efficacy.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Diabrotica barberi Smith and Lawrence — Northern corn rootworm (310)

2. Candidate biocontrol agents (when known and appropriate)

   Predators: Carabus nemoralis Carabidae, Carabus fossor Carabidae, Pterostichus melanarius Carabidae, Stratiolaelaps sp. Mite, Androlaelaps sp. Mite, Lasius neoniger Ant

   Parasites: Celatoria diabroticae Tachinid, Steinernema feltiae Nematode

   Pathogens: Microsporidian Protozoan

3. Commodities

   Corn

4. Status of biocontrol research effort:

   a. Past: Limited. Minimal survey of Cornbelt. Several explorations to Peru and Mexico.

   b. Present: Microsporidia (Gregariues); nematodes.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Develop expertise in handling available biological control agents. Conduct basic laboratory and microplot research to establish environment parameters, etc., which are prerequisites to pilot field programs.

6. ARS laboratories involved (present)

   Northern Grain Insects Research Laboratory, Brookings, SD.
   Beneficial Insect Introduction Laboratory, Beltsville, MD

7. Other Federal laboratories involved (present/future)

   Columbia, MO; Charleston, SC

8. Potential State/University cooperation

   Rutgers

9. Suggested ARS contact individual(s) - (Key person)

   G. R. Sutter, Brookings, SD

10. Funds required

    $120,000

11. SY input needed

1 SY based at NGIRL to initiate disease and parasite exploration and efficacy.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Heliothis zea (Boddie) — Corn earworm, Bollworm, Tomato fruitworm (204)

2. Candidate biocontrol agents (when known and appropriate)

   Microplitis croceipes
   Trichogramma spp.
   Campoletis sorensis
   Cotesia margeniventris
   Chrysopa carnea
   Cotesia kazak
   Microplitis demolifer
   Hypersoter didymator
   Coccinelids
   NP Viruses
   Nosemia
   Various fungi

3. Commodities

   Corn, sorghum, clovers, alfalfa

4. Status of biocontrol research effort:

   a. Past: (a) Conservation approaches of natural enemies; (b) augmentation with *Trichogramma*; (c) importation of various spp.; (d) evaluation, experimentation, and some commercial use of pathogens and B.t.

   b. Present: (a) Conservation of natural enemies; (b) manipulation of entomophage behavior; (c) rearing technology of entomophages; (d) improved formulations and evaluation of pathogens and B.t.; (e) importation research with various natural enemies.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Continuation of introduction studies; improvement of formulations and evaluation of pathogens; research on role and functional mechanisms of factors influencing efficacy of natural enemies; development of *in vitro* and *in vivo* rearing and release technologies for augmentation with natural enemies; approaches for manipulation of foraging behavior; techniques for detection and forecasting the effectiveness of natural enemy populations.

6. ARS laboratories involved (present)

Insect Attractants, Behavior, and Basic Biology Research Laboratory, Gainesville, FL
Insect Biology and Population Management Laboratory, Gainesville, FL
Southern Field Crops Insect Management Laboratory, Stoneville, MS
Cotton Insect Research Laboratory, TX
Cotton Insects Research, Brownsville, TX
Biocontrol Insects Research Laboratory, Columbia, MO

7. Other Federal laboratories involved (present/future)

None

8. Potential State/University cooperation

Unlimited

9. Suggested ARS contact individual(s) - (Key person)

E. G. King, Stoneville, MS
C. E. Rogers, Tifton, GA
H. Oberlander, Gainesville, FL
D. Bull, College Station, TX
C. Ignoffo, Columbia, MO

10. Funds required

$2,250,000

11. SY input needed

15 SYs total

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Ostrinia nulilalis (Hubner) — European corn borer (249)

2. Candidate biocontrol agents (when known and appropriate)

Parasitoids: *Lydella thompsoni*, *Lixophaga variabilis*, *Lixophaga diatreae*, *Eriborns terebrans*, *Macrocentrus grandii*, *Sympiesis viridula*, *Trichogramma* spp.

Pathogens: *Nosema pyrausta*, *Nosema* sp., *Varimorpha nexatrix*, *Barimorpha* sp., *Beauveria bassiana*, *Bacillus thuringiensis*, nuclear polyhedrosis viruses isolated from *Audographa californica* and *Rachiplusia on*.

Nematodes: *Neoplectana carpocapsae*

3. Commodities

Field corn, popcorn, sweet corn, snapbeans, green peppers, sorghum

4. Status of biocontrol research effort:

a. Past: Introduction of approximately 25 larval parasitoids were randomly released between 1920 and 1954. Very few parasitoids became established, i.e., *Lydella thompsoni*, *Eriborus terebrans*, *Macrocentrus grandii*, and *Sympiesis viridula*. Presently *E. terebrans* amd *M. grandii* are the only two that are received in any substantial number. The microsporidium, *Nosema pyrausta*, was isolated from the corn borer during the late 1940's and early 1950's.

b. Present: Basic biology research is ongoing addressing the relationships between parasitoids, pathogens, and has to determine the compatibility of these organisms. *B. thuringiensis* is a known effacious pathogen. Ecology of *N. pyrausta* is being studied relative to reduced tillage practices.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Augmentaton - *Macrocentrus grandii* and *Lydella thompsoni*
Introduction - *Lixophaga* sp. microsporidia
Pathology - Microsporidia, *B. thuringiensis*, viruses, *B. bassiana*

6. ARS laboratories involved (present)

Corn Insects Research Laboratory, Ankeny, IA

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

Several State universities in the north central region, and Connecticut Agricultural Experiment Station, New Haven, CN

9. Suggested ARS contact individual(s) - (Key person)

Leslie C. Lewis, Ankeny, IA

10. Funds required

$300,000

11. SY input needed

2 SYs

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Melonoplus spp. — Grasshoppers (281, 282, 283, 284, 285, 291, 292)

2. Candidate biocontrol agents (when known and appropriate)

   Microsporidia, entomopox viruses, Entomophaga, Entomophagous diptera

3. Commodities

   Crops, forage (range and pasture)

4. Status of biocontrol research effort:

   a. Past: Malameba locustae, 1936 augmentative release failed to alter host densities. Nosema locustae registered. In commercial production and being used for control of grasshoppers in gardens and rangelands. Several diptera introduced from Europe would not establish.

   b. Present: Evaluation of native and exotic microsporidia and entomopo viruses in laboratory and small field plots (ARS, Bozeman). Laboratory and small field plot evaluations of Entomophaga grylli complex (ARS, Ithaca, State, North Dakota, Kansas, Idaho). Field manipulation of parasite densities (ARS, Bozeman).

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentative application of microbial pesticides for long-termed density regulation appears most appropriate. Isolation and/or development (genetically altered) of a short termed control microbial pesticide would be widely accepted.

6. ARS laboratories involved (present)

   ARS Rangeland Insect Laboratory, Bozeman, MT
   ARS Insect Pathology Laboratory, Ithaca, NY

7. Other Federal laboratories involved (present/future)

   Unknown

8. Potential State/University cooperation

   Expected continued cooperation with North Dakota, Idaho, Wyoming, and Montana with funds cooperation could also be expected from Kansas, Nebraska, South Dakota, Oklahoma, and Colorado.

9. Suggested ARS contact individual(s) - (Key person)

J. E. Henry
Bozeman, MT

10. Funds required

$300,000

11. SY input needed

2 Sys (a pathologist on viruses and 1 ecologist for parasite and predator research at Bozeman)

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Sitona hispidulus (Fabricius) — Clover root curculio (52)

2. Candidate biocontrol agents (when known and appropriate)

   Parasites: *Anaphes dianae*, *Microctonus* sp., *Beauveria* sp.

3. Commodities

   Alfalfa, clover

4. Status of biocontrol research effort:

   a. Past: Very little that is not ongoing.

   b. Present: Brief introduction of egg parasite *Anaphes dianae*, with possible establishment; introduction of proper strain of *Microctonus* spp. because establishment of this genus yet unknown against *Sitona*.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction of natural enemies; possible exploration for and introduction of pathogen, *Beauveria*, and other pathogens.

6. ARS laboratories involved (present)

   Beneficial Insects Research Laboratory, Newark, DE
   ARS Lab at University of Nebraska, Lincoln, NE
   Possible USDA-ARS lab at Beltsville, MD (Ratcliffe)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Department of Entomology, University of Kentucky, Lexington
   Illinois Natural History Survey, Urbana

9. Suggested ARS contact individual(s) - (Key person)

   G. R. Manglitz, Lincoln, NE
   Richard Dysart, Newark, DE

10. Funds required

    No new funds required if current level of research continues.

11. SY input needed

    No new SYs required if current level of research continues.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Adelphocoris lineolatus (Goeze) — Alfalfa plant bug (96)

2. Candidate biocontrol agents (when known and appropriate)

   Peristenus spp. parasites

3. Commodities

   Alfalfa

4. Status of biocontrol research effort:

   a. Past: None

   b. Present: Several parasites released, too soon to know outcome.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction (classical); pest is introduced.

6. ARS laboratories involved (present)

   Newark, DE; Paris, France

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   None

9. Suggested ARS contact individual(s) - (Key person)

   W. H. Day, Newark, DE

10. Funds required

    None; present level of effort

11. SY input needed

    None, present level of effort

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Mirid bugs: Lygus spp. — Tarnished plant bug and related spp. (100)

2. Candidate biocontrol agents (when known and appropriate)

Parasites: Peristenus spp.

3. Commodities

Alfalfa (also vegetables, fruit, cotton)

4. Status of biocontrol research effort:

   a. Past: Work began in early 1960's, insufficient effort at first.

   b. Present: Recent work more intensive, too soon to know results; Lygus spp. are native, but parasites from related spp. are satisfactory in lab tests.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Introduction of European parasites (classical).

6. ARS laboratories involved (present)

Newark, DE; Tucson, AZ; Stoneville, MS; Dallas, TX; Paris, France

7. Other Federal laboratories involved (present/future)

None

8. Potential State/University cooperation

M. F. Schuster, Texas A&M, Dallas

9. Suggested ARS contact individual(s) - (Key person)

W. H. Day, Newark, DE
[H. M. Graham (Tucson) and O. P. Young (Stoneville)]

10. Funds required

Existing funds adequate for present level of effort.

11. SY input needed

Existing SY adequate for present level of effort.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Spodoptera frugiperda — Fall armyworm (211)

2. Candidate biocontrol agents (when known and appropriate)

   Chelonus insularis - augmentation. Twenty-one species of parasites in Central and South America which do not parasitize FAW in the United States.

3. Commodities

   Corn, Bermuda grass, sorghum, peanuts

4. Status of biocontrol research effort:

   a. Past: Only very limited exploration in Central and South America has been carried out. Three attempts to establish parasites in the overwintering area (south Florida) have not been successful.

   b. Present: No active and coordinated biological control program is currently being supported by ARS or any university. Analysis of FAW larval populations in south Florida indicates that an effective density dependent regulator is not present. Studies on the host finding behavior of a pupal parasite are now underway.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   a. Determine principal larval population regulators in Central and South America and attempt to establish these parasites in the United States.
   b. Determine parasite species attacking FAW on hosts other than corn.
   c. Investigate the potential for augmentation releases using *Chelonus insularis*.

6. ARS laboratories involved (present)

   Insect Attractants, Behavior, and Basic Biology Research Laboratory, Gainesville, FL
   Insect Biology and Population Management Research Laboratory, Tifton, GA

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

Agricultural Research and Education Center, Department of Entomology and Nematology, University of Florida, Homestead, FL

9. Suggested ARS contact individual(s) - (Key person)

T. R. Ashley, Gainesville, FL
H. R. Gross, Tifton, GA
S. Pair, Tifton, GA
A. N. Sparks (FAW Regional Research Coordinator). Tifton, GA

10. Funds required

$200,000

11. SY input needed

2.0 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Pseudaletia unipuncta (Haworth) — Armyworm (208)

2. Candidate biocontrol agents (when known and appropriate)

   Native parasite *Apanteles militaris* could be used in an IPM type program.

3. Commodities

   Wheat, corn, small grains

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Can distinguish parasitism in the field, information which could be incorporated into the decision-making processes in regard to economic thresholds, and treatments recommendations.

6. ARS laboratories involved (present)

   None at present.

7. Other Federal laboratories involved (present/future)

   None at present.

8. Potential State/University cooperation

   North Central and Plain State Universities

9. Suggested ARS contact individual(s) - (Key person)

   B. Puttler
   Columbia, MO (for information)

10. Funds required

    $100,000 to initiate program

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Agrotis ipsilon — Black cutworm (196)

2. Candidate biocontrol agents (when known and appropriate)

   Microsporidia, nuclear polyhedrosis viruses, approximately 6 species of parasitoids, mermithid nematodes

3. Commodities

   Corn, vegetables, small grains

4. Status of biocontrol research effort:

   a. Past: Very little.

   b. Present: Minimal.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Pathology, better understanding of role of parasitoids.

6. ARS laboratories involved (present)

   Corn Insects Lab, Ankeny, IA

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   University of Missouri; Iowa State; Purdue University; Ohio State; Illinois

9. Suggested ARS contact individual(s) - (Key person)

   Ben Puttler, Columbia, MO
   Les Lewis, Ankeny, IA

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Euxoa auxiliaris (Grote) — Army cutworm (201)

2. Candidate biocontrol agents (when known and appropriate)

   Viruses (pox and granulosis); Parasites

3. Commodities

   Alfalfa, small grains

4. Status of biocontrol research effort:

   a. Past: Pathogenesis of viral diseases. Surveys of incidence and identification of parasites.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Several effective viral diseases were isolated, biogenesis determined, and laboratory efficacy determined. Several parasites (*Copidosoma bakeri*) were isolated and effective rearing techniques developed. Costs were less than $0.05/thousand. These biocontrol agents could be tested in pilot programs.

6. ARS laboratories involved (present)

   Northern Grain Insects Research Laboratory, Brookings, SD

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   Kansas, Oklahoma, Nebraska, Montana

9. Suggested ARS contact individual(s) - (Key person)

   G. R. Sutter, Brookings, SD

10. Funds required

    $60,000

11. SY input needed

    0.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Diatraea grandiosella (Dyar) — Southwestern corn borer (237)

2. Candidate biocontrol agents (when known and appropriate)

   Parasitoids: *Iphiaulax kimballi*; pathogens

3. Commodities

   Corn

4. Status of biocontrol research effort:

   a. Past: Introduced the parasitoid *Iphiaulax kimballi* from Mexico; released in Missouri. No evidence of establishment.

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction of parasitoids, pathology

6. ARS laboratories involved (present)

   Host Plant Resistance at Columbia, MO, and Starkville, MS

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   Dean Barry, Columbia, MO
   Frank Davis, Starkville, MS

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Empoasca fabae (Harris) — Potato leafhopper (303)

2. Candidate biocontrol agents (when known and appropriate)

   Parasitoids: Mymarids - Angrus, Polynema, Stethynium

   Pathogen: Entomophthoacea - Erynia sp.

3. Commodities

   Alfalfa, potato, dry bean, soybeans, ornamentals

4. Status of biocontrol research effort:

   a. Past: None attempted.

   b. Present: Five species of mymarids released in 1983.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   E. fabae is a native U.S. pest; however, there are close relatives of E. fabae both in the U.S. and world-wide. There has been little effort on importation or augmentation. A recent discovery of a fungal pathogen (Entomophthoracea: Eryria sp.) provides another route to provide control, but as yet, this is untested.

6. ARS laboratories involved (present)

   Beneficial Insects Research Laboratory, Newark, DE
   European Parasite Laboratory, Paris, France

7. Other Federal laboratories involved (present/future)

   N/A

8. Potential State/University cooperation

   NCR - 149

9. Suggested ARS contact individual(s) - (Key person)

   R. Hendrickson, Newark, DE

10. Funds required

    $150,000

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

<u>Hyperea postica/brunneipennis</u> complex — Western and Egyptian alfalfa weevils (44)

2. Candidate biocontrol agents (when known and appropriate)

<u>Microctonus</u> (2 spp.), <u>Bathyplectes</u> (2 spp.), <u>Tetrastichus</u> (1 sp.)

3. Commodities

Alfalfa

4. Status of biocontrol research effort:

a. Past: Excellent success in East; fair results (for parasitic spp. established) so far in West.

b. Present: Ongoing (APHIS) in western U.S.; too soon to judge success.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Introduction (classical) of exotic spp.

6. ARS laboratories involved (present)

None at present (APHIS at Niles, MI)

7. Other Federal laboratories involved (present/future)

Newark, DE (Consultant role only--ARS)

8. Potential State/University cooperation

None

9. Suggested ARS contact individual(s) - (Key person)

W. H. Day, Newark, DE (Consultant role only--ARS)

10. Funds required

No new funds at this time (consultant role only--ARS)

11. SY input needed

No new SY at this time (consultant role only--ARS)

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Schizaphis gramium (Rondani) — Greenbug (135)

2. Candidate biocontrol agents (when known and appropriate)

Parasites: Lysephlebus testocipes, Aplelsunus nigritus

Predators: Sycmnas sp. Hippodamia couvergens, H. parenthesis (Say), H. tredecimpunctata tibialis (Say)

3. Commodities

Small grains, sorghum

4. Status of biocontrol research effort:

a. Past: Release of cocinellids. Incidences of parasitism.

b. Present: Phenology of predators.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

Stillwater, OK
Brookings, SD

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

Texas, Oklahoma, Kansas, North Dakota

9. Suggested ARS contact individual(s) - (Key person)

R. W. Kieckhefer, Brookings, SD

10. Funds required

$60,000

11. SY input needed

0.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Diatroera saccharalis (F.) — Sugarcane borer (238)

2. Candidate biocontrol agents (when known and appropriate)

   Egg/larval/pupal parasites

3. Commodities

   Sugarcane

4. Status of biocontrol research effort:

   a. Past: Numerous parasites introduced, of which 3 established in Florida (*Lixophaga diatraea*, *Apanteles flavipes*, *Agathis stigmatera*), Louisiana (*L. diatraeae*, *A. stigmatera*), and Texas (*A. flavipes*); technical feasibility of controlling sugarcane borer in sugarcane by augmentative release of *L. diatraea* demonstrated.

   b. Present: Slight, less than 0.2 SY

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction, but may be feasible to augment larval parasites early season because of favorable system and crop for biological control.

6. ARS laboratories involved (present)

   U.S. Sugar Station, Houma, LA
   USDA Sugarcane Field Station, Canal Point, FL
   Southern Field Crops Insect Mangement Laboratory, Stoneville, MS

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Texas A&M University, College Station, TX
   Florida State University, Gainesville, FL

9. Suggested ARS contact individual(s) - (Key person)

   Sess D. Hensley, U.S. Sugar Station, Houma, LA
   Omelio Sosa, Jr., USDA Sugarcane Field Station, Canal Point, FL
   E. G. King, Southern Field Crops Insect Management Laboratory, Stoneville, MS

10. Funds required

    $100,000

11. SY input needed

2/3 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Contarinia sorghicola (Coquillett) — Sorghum midge (71)

2. Candidate biocontrol agents (when known and appropriate)

   Unknown

3. Commodities

   Grain sorghum

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: 0.5 SY at Texas A&M University

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction

6. ARS laboratories involved (present)

   Southern Field Crop Insect Management Laboratory, Stoneville, MS
   Southern Grain Insects Research Laboratory, Tifton, GA

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   Texas A&M University, College Station, TX

9. Suggested ARS contact individual(s) - (Key person)

   W. A. Jones, Stoneville, MS

10. Funds required

    $75,000

11. SY input needed

    0.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Mayetiola destructor (Say) — Hessian fly (70)

2. Candidate biocontrol agents (when known and appropriate)

   Parasites that would be found in Asia or Middle East

3. Commodities

   Wheat

4. Status of biocontrol research effort:

   a. Past: Early work done late 1800's; lost 1935-39.

   b. Present: None with parasites; all on host plant resistance

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction done is the early days came from the wrong area. Hessian fly is native to Asia and Middle East where wheat also had it origin. Suggest exploration into native home of pest and host plant. Hopefully, more specific parasites could be obtained than already present.

6. ARS laboratories involved (present)

   J. Hatchett, Manhattan, KS
   J. Foster, West Lafayette, IN

7. Other Federal laboratories involved (present/future)

   Columbia, MO (quarantine facility)

8. Potential State/University cooperation

   Kansas State University; University of Missouri; other midwest and plains States

9. Suggested ARS contact individual(s) - (Key person)

   B. Puttler
   Columbia, MO (For information)

10. Funds required

    $10,000 initial introduction and importation. Then money needed dependent on success of exploration (TDY)

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

   <u>Rhopalosiphum</u> <u>maidus</u> (Fitch) | Corn leaf aphid (134)

2. Candidate biocontrol agents (when known and appropriate)

   Parasites; Predators

3. Commodities

   Small grains, corn sorghum

4. Status of biocontrol research effort:

   a. Past: Predators: coccinellids

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Northern Grain Insects Research Laboratory, Brookings, SD

7. Other Federal laboratories involved (present/future)

   Stillwater, OK

8. Potential State/University cooperation

   South Dakota State University

9. Suggested ARS contact individual(s) - (Key person)

   R. W. Kieckhefer, Brookings, SD

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Lissorhoptrus oryzophilus Kuschel — Rice water weevil (46)

2. Candidate biocontrol agents (when known and appropriate)

   Agents capable of attacking the egg, larval and/or pupal stage beneath water

3. Commodities

   Rice

4. Status of biocontrol research effort:

   a. Past: None.
   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   Southern Field Crop Insect Management Laboratory, Stoneville, MS
   Rice Experiment Station, Crowley, LA

8. Potential State/University cooperation

   Dr. Phil Tugwell, Dept. Entomology, Univ. AR, Fayetteville
   Dr. A. A. Griyarick, Dept. Ent., Univ. CA, Davis
   Dr. Michael W. Way, Texas A&M Res. Ext. Center, Beaumont

9. Suggested ARS contact individual(s) - (Key person)

   W. A. Jones, Stoneville, MS
   John Robinson, Crowley, LA

10. Funds required

    $75,000/year for 5 years

11. SY input needed

    .5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Hypera meles (F.) — Clover head weevil (45)

2. Candidate biocontrol agents (when known and appropriate)

   Larval parasite *Bathyplectes* sp. and adult parasite *Microctonus* sp.

3. Commodities

   Red and crimson clover and other clovers

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: Some effort made to use *Microctonus aethiopoides* on the alfalfa weevil.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Discover natural enemies specific to this sp. of *Hypera*

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None known at present. Some work being done in Gulf States.

8. Potential State/University cooperation

   Gulf State Universities

9. Suggested ARS contact individual(s) - (Key person)

   B. Puttler
   Columbia, MO (for information)

10. Funds required

    TDY and in cooperation with EPL approximately $20,000 initially.

11. SY input needed

    .5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

<u>Autographa californica</u> (Speyer) — Alfalfa looper (200)

2. Candidate biocontrol agents (when known and appropriate)

Attempt to collect parasites in Nearctic and Neotropical region for introduction.

3. Commodities

Alfalfa and vegetables

4. Status of biocontrol research effort:

a. Past: None.

b. Present: Only determining native natural enemies.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Introduce parasites from related loopers some of these possibly could be used in effort to establish them on other nearctic loopers.

6. ARS laboratories involved (present)

None

7. Other Federal laboratories involved (present/future)

Yakima, WA

8. Potential State/University cooperation

Oregon State University, University of California

9. Suggested ARS contact individual(s) - (Key person)

B. Puttler
Columbia, MO (for information)

10. Funds required

$50-100,000

11. SY input needed

.5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Hemileuca oliviae Cockerell — Range caterpillar (253)

2. Candidate biocontrol agents (when known and appropriate)

Viruses, *Bacillus thuringiensis*, possible Hymenopterous parasites.

3. Commodities

Forage (range)

4. Status of biocontrol research effort:

   a. Past: Field evaluation of B.t. demonstrated efficacy and cost effectiveness. However, current control is with chemicals because of cost factor.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Additional research required on more effective B.t. strains. Isolation and testing of baculovirus (NPV).

6. ARS laboratories involved (present)

None

7. Other Federal laboratories involved (present/future)

None

8. Potential State/University cooperation

New Mexico

9. Suggested ARS contact individual(s) - (Key person)

J. E. Henry
Bozeman, MT

10. Funds required

$150,000

11. SY input needed

1 SY (Pathologist or Biocontrol Entomologist)

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

PRIORITIES SUMMARY D.1.3

Chairman: Harry Graham

Team Members: Jack Coulson, Ed Dougherty, Carll Goodpasture, Akey Hung, Carlo Ignoffo, Walker Jones, Juan Lopez, William Nickle, Janine Powell, Richard Ridgway, Robert Schroder, and James Smith

I. Problem Title:

Biological control of insect pests of row and specialty crops

II. Problem Statement:

A variety of pests attack row and specialty crops in the U.S. causing losses in yield and quality. In addition, quantities of pesticides are used to control these pests that may cause adverse environmental affects leading to the buildup of other pests as well as affecting other nontarget organisms. There are a number of pests that attack these crops that may be amendable to biological control using various systems that provide an opportunity to reduce the quantity of pesticides used and the cost of production of these crops.

III. Criteria for Priorities:

a. Economic importance of the pests on a national basis.
b. Effectiveness of current controls.
c. Potential for success of biocontrol measures.
d. Past work on biocontrol.
e. Availability of biocontrol agents.

IV. List of Priorities:

The following list ranks the pests into Categories I (highest priority), II and III, as candidates for biocontrol, and also within categories I and II. Many of the pests included in the original list were not included and some insects not on the original list were added. Chairman's Note: Many of the members of the group felt we did not know enough about some of the pests or crops. This list should be reviewed by specialists on the specific crops and insects.

Category I (Highest Priority):

1. *Heliothis zea* (204)	Bollworm, corn earworm
2. *Heliothis virescens* (203)	Tobacco budworm
3. *Spodoptera* spp. (210-211)	Beet and fall armyworms
4. *Leptinotarsa decemlineata* (24)	Colorado potato beetle
5. *Bemisia tabaci* (112)	Sweet potato white fly
6. *Nezara viridula* (106)	Southern green stinkbug

Category II:

1.	*Anthonomus grandis* (31)	Boll weevil
2.	*Trichoplusia ni* (212)	Cabbage looper
3.	*Epilachna varivestis* (28)	Mexican bean beetle
4.	*Pseudoplusia includens* (209)	Soybean looper
5.	*Anticarsia gemmatalis* (199)	Velvetbean caterpillar
6.	*Diabrotica* spp. (21-22)	Cucumber beetles

Category III:

Cutworm complex (*Feltia*, *Agrotis*, *Euxoa* (201, 202, 196)	Cutworms
Empoasca spp. & *Circulifer tenellus* (303, 139)	Leafhoppers
Mirine plant bugs (100, 104)	Lygus bugs, cotton fleahopper
Tetranychus urticae, etc. (9)	Spidermites
Artogeia rapae (318)	Imported cabbage worm
Epitrix & *Altica* (328, 355, 356)	Fleabeetles
Delia spp. (299, 300)	Root maggots
Liriomyza (67-68)	Dipterous leafminers
Ostrinia nubilalis (249)	European corn borer
Crioceris spp. (296, 297)	Asparagus beetles
Ceratitis capitata (90)	Mediterranean fruit fly
Dacus cucurbitae (91)	Melon fly
Myzus persicae (131)	Green peach aphid
Trialeurodes vaporariorum (116)	Greenhouse whitefly

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   <u>Heliothis zea</u> — Bollworm, Tomato fruitworm

2. Candidate biocontrol agents (when known and appropriate)

   Numerous parasites, predators, and pathogens.

3. Commodities

   Corn, cotton, soybeans, tomatoes, lettuce, peanuts, sesame, tobacco

4. Status of biocontrol research effort:

   a. Past: Several parasites introduced, but none established; pilot test using augmentation of <u>Trichogramma</u> indicated it was not economically feasible at present; pathogens demonstrated effective, but not commercially implemented.

   b. Present: Limited classical biocontrol efforts; work on conservation and management of indigenous natural enemies; rearing of parasites and predators; basic and applied studies on pathogens.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation, conservation, manipulation, introduction of parasites and predators, studies on pathogens.

6. ARS laboratories involved (present)

   Stoneville, MS; College Station, TX; Tifton, GA; Gainesville, FL; Columbia, MO; Tucson, AZ; Brownsville, TX; Oxford, NC; Florence, SC; Sevres, France; SEL & BIIL, Beltsville, MD

7. Other Federal laboratories involved (present/future)

   Future: APHIS

8. Potential State/University cooperation

   Various States - Mississippi State; Clemson; TAMU; University of FL; LSU; Auburn; NC State; Arkansas

9. Suggested ARS contact individual(s) - (Key person)

   E. G. King, Stoneville, MS
   H. Dulmage, Brownsville, TX
   B. D. Perkins, Sevres, France

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.09.1a and 1b

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Heliothis virescens — Tobacco budworm

2. Candidate biocontrol agents (when known and appropriate)

   Numerous predators, parasites, diseases

3. Commodities

   Cotton, tomatoes, lettuce, soybeans, tobacco

4. Status of biocontrol research effort:

   a. Past: Several parasites have been introduced but none established; augmentation release of *Trichogramma* tested, not ecologically feasible; viruses available commercially, but not accepted.

   b. Present: Limited classical BC; major efforts on manipulation and conservation of indigenous natural enemies; pathogens, parasites, and predator rearing.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation, conservation and manipulation of indigenous parasites and predators; diseases; exploration and introduction.

6. ARS laboratories involved (present)

   Stoneville, MS; Gainesville, FL; Brownsville, TX; Oxford, NC; Columbia, MO; Tucson, AZ; College Station, TX; Sevres, France; SEL & BIIL, Beltsville, MD

7. Other Federal laboratories involved (present/future)

   Future: APHIS

8. Potential State/University cooperation

   Various States - Mississippi State; Clemson, SC; TAMU; University of Florida; LSU; Auburn; NC State; Arkansas

9. Suggested ARS contact individual(s) - (Key person)

   Ed King, Stoneville, MS
   B. D. Perkins, Sevres, France
   H. Dulmage, Brownsville, TX

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.09.1a and 1b

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

   Spodoptera spp. | Fall/Beet Armyworms

2. Candidate biocontrol agents (when known and appropriate)

   Many known parasites and predators and pathogens
   Chelonus insularis - augmentation, 21 species of parasites occur in Central and South America which do not parasitize FAW in the U.S.

3. Commodities

   Sweet corn, soybeans, cotton, vegetables, peanuts

4. Status of biocontrol research effort:

   a. Past: Only very limited exploration in Central and South America has been carried out. Three attempts to establish parasites in the overwintering areas (South Florida) have not been successful.

   b. Present: No active and coordinated biological control program is currently being supported by ARS or any university. Analysis of FAW larval populations in South Florida indicates that an effective density dependent regulator is not present. Studies on the host finding behavior of a pupal parasite are now underway.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction of parasites and pathogens. Conservation, augmentation, and pathology.

6. ARS laboratories involved (present)

   Tifton, GA; Brownsville, TX; Columbia, MO; Phoenix, AZ; Tucson, AZ; Gainesville, FL; Sevres, France; SEL, IPL, Beltsville, MD

7. Other Federal laboratories involved (present/future)

   Future: APHIS/PPQ Biocontrol Lab, Mission, TX

8. Potential State/University cooperation

   Clemson University; Mississippi State University; University of Florida, Homestead

9. Suggested ARS contact individual(s) - (Key person)

   A. N. Sparks, Tifton, GA
   T. R. Ashley, Gainesville, FL
   B. D. Perkins, Sevres, France
   H. Dulmage, Brownsville, TX

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.09.1a and 1b

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Leptinotarsa decimlineata — Colorado potato beetle

2. Candidate biocontrol agents (when known and appropriate)

   Beauvaria bassiana *B t.*, *Edovum puttleri*, *Doryphorophaga*, *Perillus*, *Hexamermis*

3. Commodities

   Potatoes, tomatoes, eggplants

4. Status of biocontrol research effort:

   a. Past: Very little in U.S. until recently. Much importation work in Europe.

   b. Present: Work on candidate biocontrol agents listed above is now in progress at various location in U.S.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation (*Edovum*, *Doryphorophaga*, *Perillus*)
   Conservation (*Perillus*)
   Introduction (*Hexamermis*, Mexican natural enemies)
   Pathology (*B.t.*, *Beauveria*)

6. ARS laboratories involved (present)

   Yakima, WA; Beltsville, MD; Newark, DE; Columbia, MO

7. Other Federal laboratories involved (present/future)

   APHIS/PPQ Biocontrol Laboratory, Mission, TX; Economic Research Service

8. Potential State/University cooperation

   Virginia Truck and Ornamental Research Station, VA Department Education, Painter, VA
   Department of Entomology, Rutgers University, New Bruncwick, NJ
   Division of Plant Industry, NJ Dept Agriculture, Trenton, NJ
   Department of Entomlogy, Cornell University, Ithaca, NY
   University of Guelph, Guelph, Ontario
   University of Rhode Island
   University of Utah
   Maryland Department of Agriculture

9. Suggested ARS contact individual(s) - (Key person)

R. F. W. Schroder
USDA-ARS-NER
Beneficial Insect Introduction Laboratory
Bldg. 264, BARC-East
Beltsville, MD 20705

10. Funds required

11. SY input needed

Current SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.09.1a and 1b

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Bemisia tabaci — Sweetpotato whitefly

2. Candidate biocontrol agents (when known and appropriate)

   Encarsia and *Eretniocerus* parasites. Predators.

3. Commodities

   Cotton, squash, lettuce, sweetpotatoes, tomatoes, beans, cucumbers, etc.

4. Status of biocontrol research effort:

   a. Past: Extensive parasites in U.S. have been identified. Extensive research on biocontrol agents has been done in Far East. Known parasites occur in Africa and Mediterranean and other Old World locations.

   b. Present: New thrust to develop classical biocontrol program in Southwest being proposed because of 5 viruses being transmitted, some in epidemic proportions.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction and some augmentation, possibly pathology. Conservation approach (correct mismanagement of pesticides, and modification of agronomic practices).

6. ARS laboratories involved (present)

   Riverside, CA; Phoenix, AZ; Salinas, CA

7. Other Federal laboratories involved (present/future)

   Future: Stoneville, MS

8. Potential State/University cooperation

   University of California, Riverside; University of Arizona, Tucson

9. Suggested ARS contact individual(s) - (Key person)

   D. E. Meyerdirk, Riverside, CA

10. Funds required

$650,000; 5 year Pilot Test Project Proposal

11. SY input needed

Current: 0.5 SY; Needed: 2 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.09.1a

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

Nezara viridula (L.) — Southern green stink bug

2. Candidate biocontrol agents (when known and appropriate)

Parasitoids:
Trissolcus basalis (Wallastor) - egg parasitoids
Trissolcus mitsukurii Ashmead - egg parasitoids
Telenomus nakagawai Thomson - egg parasitoids
Ooencyrtus spp. - egg parasitoids
Gryon antestiae Nixon - egg parasitoids
Telenomus chloropus
Tachinidae: *Trichopoda pennipes* (f.)
Eutrichopodopsis nitens (Blanchard)

Predators: Very effective on eggs and small nymphs

3. Commodities

Soybeans, cowpeas, truck crops, sorghum

4. Status of biocontrol research effort:

a. Past: Introduction in Hawaii resulted in establishment of *Trissolcus baselis* and *Trichopoda pennipes*. Other limited introduction for study.

b. Present: Introduction of exotic parasitoids for study and possible release.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Introduction of parasitoids of eggs and adults from the Orient and South America.

6. ARS laboratories involved (present)

Stoneville, MS

7. Other Federal laboratories involved (present/future)

None

8. Potential State/University cooperation

Louisiana State University

9. Suggested ARS contact individual(s) - (Key person)

Dr. Walker A. Jones
USDA-ARS-SR
P.O. Box 225
Stoneville, MS 38776

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.09.1a

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Anthonomus grandis — Boll weevil

2. Candidate biocontrol agents (when known and appropriate)

   ?

3. Commodities

   Cotton

4. Status of biocontrol research effort:

   a. Past: *Bracon kirkpatricki* introduced; *B. millita* conservation and augmentation; predation by fire ant and other predators.

   b. Present: Exploration in Mexico and Central America; parasites in quarantine, some introduced parasites being released.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Exploration and introduction, augmentation and conservation of parasites.

6. ARS laboratories involved (present)

   Boll Weevil Research Laboratory, Mississippi State, MS

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Texas A&M University; Mississippi State; Oklahoma State

9. Suggested ARS contact individual(s) - (Key person)

   E. P. Lloyd
   USDA-ARS-SR
   Boll Weevil Research Laboratory
   P.O. Box 5367
   Mississippi State, MS

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.09.1a

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Trichoplusia ni — Cabbage looper

2. Candidate biocontrol agents (when known and appropriate)

   Pathogens, parasites, predators

3. Commodities

   Cotton, cole crops, lettuce, soybeans

4. Status of biocontrol research effort:

   a. Past: Pathogens technically feasible, not commercial; augmentation, and conservation of indigenous natural enemies.

   b. Present: Evaluating introduced parasites of Plusiinae.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction of exotic natural enemies; augmentation; pathogens.

6. ARS laboratories involved (present)

   Columbia, MO

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Arkansas, California

9. Suggested ARS contact individual(s) - (Key person)

   Patrick Vail, Fresno, CA (pathogens)
   H. Dulmage, Brownsville, TX

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.09.1a and 1b

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Epilachna varivestis — Mexican bean beetle

2. Candidate biocontrol agents (when known and appropriate)

   Pediobius foveolatus
   Coccipolipus epilachnae (ectoparasitic mite)
   Lydinolydella sp. (Tachnid)
   Nothoserphus sp. Proctotrupid from Asia

3. Commodities

   Soybeans, garden variety beans.

4. Status of biocontrol research effort:

   a. Past: Biological control potential by *P. foveolatus* clearly demonstrated by U. of Maryland. Earlier work in South America and Mexico on tachnid parasites; varied in effectiveness. *C. epilachnae* from Central America significantly reduced longevity and fecundity of MBB. PL-480 project on natural enemies in Pakistan.

   b. Present: APHIS demonstration on broad scale inoculative releases of *P. faveolatus* in Maryland, New Jersey, Virginia, and Ohio. BIRL research on Proctotrupid from Asia. Field release and evaluation of *C. epilachnae* in Beltsville.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation would involve *P. foveolatus* as in the past. Introductions involve the rest listed in 2 above.

6. ARS laboratories involved (present)

   Beneficial Insect Introduction Laboratory
   Beneficial Insects Research Laboratory

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   MD Dept. of Agriculture, U. of Maryland, Purdue Univ., VA Dept. of Agriculture, U. of Delaware, NJ Dept. of Agriculture, Ohio State Univ.

9. Suggested ARS contact individual(s) - (Key person)

   Paul Schaeffer, BIRL, Newark, DE

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Pseudoplusia includens (Walker) — Soybean looper

2. Candidate biocontrol agents (when known and appropriate)

   Numerous parasitoids, predators, and pathogens

3. Commodities

   Soybeans, peanuts, and cotton

4. Status of biocontrol research effort:

   a. Past: Importation of parasitoids and pathogens from South America, Central America, and Australia.

   b. Present: Strains of natural enemies from different areas may be more effective if introduced into other areas where a pest occurs. There are many native parasitoids of the soybean looper:

      Apanteles spp.
      Cupidosoma truncatellum (Dalman) (*Litomastix bakeri*)
      Lespesia aletiae (Riley)
      Meteorus autopuplae Mueselback
      Ragas spp.
      Mesochorus spp.
      Brachymeria ovate (Say)

   Pathogens: Viruses - NPV; fungi - *Nomuraea* and *Entomophthora*; bacteria - *B.t.*; microsporidians.

   Parasitoids indigenous and previously imported being studied (*Microcharops bimaculata* , *Varia riralis*, *Microplitis demolitor*, etc.)

   Pathogens being studied.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Importation, augmentation, conservation, pathology. Many countries have parasitoids of plusiine loopers that may have great potential.

6. ARS laboratories involved (present)

   Stoneville, MS

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

Experiment Stations: SC, CA, FL, AR, AL

9. Suggested ARS contact individual(s) - (Key person)

Dr. Walker A. Jones
USDA-ARS-SR
P.O. Box 225
Stoneville, MS 38776

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.09.1a and 1b

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Anticarsia gemmalais Hubner — Velvetbean caterpillar

2. Candidate biocontrol agents (when known and appropriate)

   Parasites:
   Ichncumonidae: *Microcharops bimaculata*
   Corsoncus magus
   Braconidae: *Zelomorpha* sp.
   Glyptapanteles sp.
   Eulophidae: *Euplectrus puttleri*

   Pathogens:
   Nomuraea rileyi
   NPV

3. Commodities

   Soybeans, peanuts

4. Status of biocontrol research effort:

   a. Past: Importation of parasites and pathogens from South America. One parasite, *E. puttleri*, and one NPV established. Other parasites released in southern Florida.

   b. Present: Some parasites currently being released in southern Florida for attempted establishement.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Establish exotic parasites and pathogens.

6. ARS laboratories involved (present)

   Stoneville, MS

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   University of Florida

9. Suggested ARS contact individual(s) - (Key person)

   Dr. Janine Powell
   USDA-ARS-SR
   P.O. Box 225
   Stoneville, MS 38776

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

   2.4.09.1a and 1b

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Diabrotica spp. — Rootworms

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   Cucurbits, sweet corn

4. Status of biocontrol research effort:

   a. Past: Limited - Minimal survey of Cornbelt. Several explorations to Peru and Mexico.

   b. Present: Microsporidia (Gregarines), nematodes

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation, pathology.

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

   Beneficial Insect Introduction Laboratory, ARS, Beltsville, Md.
   No. Grain Insects Research Laboratory, ARS, Brookings, S.D.

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   J. J. Jackson, G. R. Sutter, J. L. Krysan, Brookings, SD
   R. F. W. Schroder, Beltsville, MD

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.09.1a and 1b

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Liriomyza spp. — Dipterous Leafminers

2. Candidate biocontrol agents (when known and appropriate)

   Parasites

3. Commodities

   Various vegetable crops

4. Status of biocontrol research effort:

   a. Past: Unknown

   b. Present: Conservation

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Exploration, conservation

6. ARS laboratories involved (present)

   Weslaco, TX; Newark, DE

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   University of Florida, University of California

9. Suggested ARS contact individual(s) - (Key person)

   R. Hendrickson, Newark, DE
   Chandler, Weslaco, TX

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.09.1a

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Crioceris spp. — Asparagus beetles, common, spotted

2. Candidate biocontrol agents (when known and appropriate)

   Lemophagus, Tetrastichus, Meigenia

3. Commodities

   Asparagus

4. Status of biocontrol research effort:

   a. Past: 1930-39, ended because WW II

   b. Present: Substantial releases

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction for total 3 years.

6. ARS laboratories involved (present)

   BIIL, Beltsville; BIRL, Newark, DE; Yakima, WA; EPL, Paris, France.

7. Other Federal laboratories involved (present/future)

   Quebec, Canada

8. Potential State/University cooperation

   Texas A&M (?)

9. Suggested ARS contact individual(s) - (Key person)

   Jack Drea
   USDA-ARS-NER
   Beneficial Insect Introduction Laboratory
   Bldg. 264, BARC-East
   Beltsville, MD 20705

10. Funds required

??

11. SY input needed

1

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

??

PRIORITIES SUMMARY E.

Chairman: Patrick Vail

Team Members: Richard Arbogast, Howard Dulmage, David Labeda, and William McGaughey

I. Problem Title:

Biological Control of Post-harvest Insects: 1) Cereals and Grains; 2) Dried Fruits and Nuts; 3) Insects of Quarantine Significance (may not be post-harvest pests in the classical sense)

II. Problem Statement:

Insects cause an average 10% loss to harvested commodities and agricultural products, and such a loss cannot be tolerated. Although chemical control measures have done much to alleviate the situation, problems of pest resistance and of residues are disadvantages. In addition, recent bans and restrictions on the use of fumigants have accented the need for alternatives. No effective new fumigants or chemical protectants have been developed recently, nor are there any prospects of availability of either in the near future.

The stability and protected nature of the commodity storage environment offers some unique opportunites for exploring the use of biological control agents. Efforts to use pathogens, parasites, and predators have shown much promise, but we should increase our efforts to use biological agents for practical control of post harvest loss-causing insects.

Due to the mode of action of parasites, predators, and pathogens, it is not felt that these organisms can be used for quarantine treatments per se. However, the restricted and relatively stable environment in which they would be used provides an excellent opportunity for reduction of commodity losses in storage. They can be used for source reduction (e.g. residual populations in empty storage facilities or storage facilities containing packaged commodities) and for direct control of insects infesting commodities. Some organisms such as pathogens, could be used to protect commodities from damage in marketing channels. Many post harvest pest problems originate in the field and carry-over into the post harvest situation (e.g. medfly, codling moth, navel orangeworm, cowpea weevil, sweetpotato weevil, and many others). In these situations natural enemies (parasites, predators, pathogens) should be exploited for use prior to harvest to reduce population carry-over into the post harvest situation in addition to control after harvest. In other words, to solve a post harvest problem, research should not be confined to solving the problem after harvest, but rather, during production of the crop if it is more advantageous.

All insects are of national importance and most are worldwide in distribution.

1. a. Scientific name:
   b. Common name:
   c. Family; Order:

2. Economic Importance of Pest:

3. Effectiveness of current control techniques:

4. Degree of control required:

5. Potential for control by biological agents:

6. Extent of prior attempts at biological control:

7. Availability of expertise:

8. Availability of biocontrol agents:

9. Type of biological control considered (e.g., pathogens, predators, parasites, augmentations, etc.):

10. Origin of infestation:

Priority Insects

1

Cadra cautella (Walker)
Plodia interpunctella (Hubner)
Anagasta kuehniella (Zeller)
Amyelois transitella (Walker)
Cydia pomonella (L.) (Quarantine significance)
Fruit flies (Ceratitis capitata (Wiedemann), Anastrepha lidens (Loew), A. suspensa (Loew), Dacus dorsalis Hendel, and Dacus cucurbitae Coquillett)-(Quarantine significance)

2

Rhyzopertha dominica (Fabricius)
Sitophilus zeamais Motschulsky
Sitophilus oryzae (L.)
Sitophilus granarius (L.)
Sitotroga cerealella (Olivier)

3

Cryptolestes spp.
Oryzaephilus surinamensis (L.)
Tribolium spp.
Carpophilus spp.

4

Quarantine Significance
Grapholita molesta (Busck)
Anarsia lineatella Zeller

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cadra cautella — Almond moth

2. Candidate biocontrol agents (when known and appropriate)

   Bacillus thuringiensis
   Bracon hebetor
   Xylocoris flavipes
   Trichogramma spp.
   Venturia canescens
   Pyremotes tritici

3. Commodities

   Grain, Processed cereal products, Groundnuts (peanuts), Tree nuts, Dried fruits

4. Status of biocontrol research effort:

   a. Past: B.t. registered for grain, laboratory studies done with all five predators and parasites.

   b. Present: B.t. studies continuing to develop more effective formulations and use patterns; pilot test with Bracon hebetor and Xylocoris flavipes on farmers' stock peanuts.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Search for more effective isolates and use patterns for B.t. For predators and parasites, pilot and field-scale studies are needed to evaluate survival, effectiveness and usefulness under field conditions.

6. ARS laboratories involved (present)

   Fresno, CA; Manhattan, KS; Savannah, GA; Brownsville, TX

7. Other Federal laboratories involved (present/future)

   Gainesville, FL

8. Potential State/University cooperation

   Kansas, Georgia, Florida, California

9. Suggested ARS contact individual(s) - (Key person)

   P. Vail
   R. Arbogast
   W. McGaughey
   H. Dulmage
   C. Beegle

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Plodia interpunctella — Indianmeal moth

2. Candidate biocontrol agents (when known and appropriate)

   Bacillus thuringiensis
   Indianmeal moth granulosis virus
   Bracon hebetor
   Xylocoris flavipes
   Trichogramma spp.
   Venturia canescens
   Pyomotes tritici

3. Commodities

   Grain, processed cereal products, groundnuts (peanuts), dried fruits and tree nuts

4. Status of biocontrol research effort:

   a. Past: B.t. registered for grain; GV ready for registration when safety tests are completed; laboratory studies done with all five predators and parasites.

   b. Present: B.t. studies continuing to develop more effective formulations and use patterns; GV under test for protection of raisins and other dried fruits and nuts in marketing channels; pilot test with *Bracon hebetor* and *Xylocoris flavipes* on farmers' stock peanuts.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Search for more effective isolates and use patterns for B.t. Studies for effective use patterns and safety for G.V. For predators and parasites pilot and field scale studies are needed to evaluate survival, effectiveness, and usefulness under field conditions.

6. ARS laboratories involved (present)

   Fresno, CA; Brownsville, TX; Manhattan, KS; Savannah, GA; Gainesville, FL

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   Kansas, Georgia, Florida, California

9. Suggested ARS contact individual(s) - (Key person)

   P. Vail
   R. Arbogast
   W. McGaughey
   H. Dulmage
   C. Beegle

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

   4.3.01.1d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Anagasta kuehniella — Mediterranean flour moth

2. Candidate biocontrol agents (when known and appropriate)

   Bacillus thuringiensis
   Bracon hebetor
   Xylocoris flavipes
   Trichogramma spp.
   Venturia canescens
   Pyemotes tritici

3. Commodities

   Processed cereal products
   grain

4. Status of biocontrol research effort:

   a. Past: B.t. tested in Europe

   b. Present: Some effort in Europe on B.t.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Search for more effective isolates and use patterns for B.t. Systematically evaluate augmentation of parasites and predators. Survey endemic biological control agents (foreign explorations).

6. ARS laboratories involved (present)

   Fresno, CA; Savannah, GA; Manhattan, KS; Brownsville, TX

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   None

9. Suggested ARS contact individual(s) - (Key person)

   P. Vail
   H. Dulmage
   W. McGaughey
   R. Arbogast

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Amyelois transitella — Navel orangeworm

2. Candidate biocontrol agents (when known and appropriate)

   Parasitoids, nematodes, non-occluded viruses

3. Commodities

   Walnuts, almonds, other fruits and nuts in field and storage.

4. Status of biocontrol research effort:

   a. Past: Parasitoids studied by U.C.; preliminary field tests with nematodes; several viruses isolated.

   b. Present: Nematodes and viruses being evaluated in laboratory/field.

5. Recommended research approaches (augmentation, introduction, microbial control, other).

   Continue developing nematodes and viruses for in field and post harvest control. Intensify field evaluations. Continue to isolate new pathogens.

6. ARS laboratories involved (present)

   Fresno, CA

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   University of California, Berkeley and Riverside

9. Suggested ARS contact individual(s) - (Key person)

   P. Vail

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1.d, 4.3.01.1.j

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cydia pomonella (quarantined) — Codling moth

2. Candidate biocontrol agents (when known and appropriate)

   Parasitoids, granulosis virus, nematodes, Bacillus thuringiensis for in-field control.

3. Commodities

   Apples, pears, stone fruits, walnuts

4. Status of biocontrol research effort:

   a. Past: Extensive work conducted in U.S., Canada and Europe on use of parasitoids and granulosis virus on apples and pears. Some research on use of granulosis virus on walnuts. Preliminary evaluation of nematode for control of diapausing larvae.

   b. Present: Granulosis virus field testing on apples, pears, walnuts. Nematode in preliminary evaluations. No evaluation of parasitoids.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   In field control of insects to reduce numbers entering post harvest situation and subsequent quarantine problems.

   Continue investigations on GV, nematodes and parasitoids. Proceed with registration of materials as indicated by efficacy data.

6. ARS laboratories involved (present)

   Fresno, Yakima, Vincennes

7. Other Federal laboratories involved (present/future)

   None/APHIS - as related to quarantine problems

8. Potential State/University cooperation

   U. C., Texas A&M

9. Suggested ARS contact individual(s) - (Key person)

   Vail, Burditt, Reed

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

4.3.01.1d, 4.3.01.01j

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Fruit flies (Quarantined insects) — Medfly, Melon, Oriental, Mexican Caribbean

   Ceratitus capitata
   Anestrepha ludens
   Anestrepha suspensa
   Dacus dorsalis
   Dacus cucurbitae

2. Candidate biocontrol agents (when known and appropriate)

   Parasites, predators, entomogenous nematodes, other microorganisms as in-field control methods for population reduction; pathogens also for replacement of malathion in bait sprays.

3. Commodities

   Fresh fruits and vegetables

4. Status of biocontrol research effort:

   a. Past: Parasitoids evaluated at several locations in Hawaii; nematodes have been studied in laboratory and small scale field tests.

   b. Present: Parasitoids and nematode continue to be evaluated. Pathogens should be investigated for both larval and adult control.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation of natural populations of parasitoids and predators; continue research on nematodes; isolate and evaluate other pathogens of fruit flies.

6. ARS laboratories involved (present)

   Hawaii, Fresno, Weslaco, Gainesville, Miami.

7. Other Federal laboratories involved (present/future)

   APHIS-Weslaco

8. Potential State/University cooperation

   Univ. of Hawaii, Texas A&M, Univ. of Fla.

9. Suggested ARS contact individual(s) - (Key person)

   Gilmore, Vail, Hart, Chambers, Spalding

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1.d, 4.3.01.1.j

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Rhizopertha dominica — Lesser Grain Borer

2. Candidate biocontrol agents (when known and appropriate)

   Xylocoris flavipes, Anisopteromalus calandrae, Pyemotes tritici

3. Commodities

   Grains

4. Status of biocontrol research effort:

   a. Past: Laboratory tests for pest suppression by above organisms.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Systematically evaluate augmentation of parasites and predators. Survey endemic parasites and predators (and also foreign explorations for other beneficial species).

6. ARS laboratories involved (present)

   Savannah, GA

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   None.

9. Suggested ARS contact individual(s) - (Key person)

   R. Arbogast

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Sitophilus spp. — Granary, Maize, and Rice weevils

2. Candidate biocontrol agents (when known and appropriate)

   Anisopteromalus calandrae

3. Commodities

   Grain

4. Status of biocontrol research effort:

   a. Past: Laboratory tests for pest suppression.

   b. Present: Studies of host parasite relationships

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Systematically evaluate augmentation of parasites. Survey endemic biological control agents (and also conduct foreign exploration for more effective agents)

6. ARS laboratories involved (present)

   Savannah, Georgia

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   None

9. Suggested ARS contact individual(s) - (Key person)

   R. Arbogast

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Sitotroga cerealella — Angoumois grain moth

2. Candidate biocontrol agents (when known and appropriate)

   Habrocytus cerealellae, *Xylocoris flavipes*, *Pyemotes tritici*, *Bacillus thuringiensis*

3. Commodities

   Grains

4. Status of biocontrol research effort:

   a. Past: Suppression by *X. flavipes* and B.t. have been tested in the lab.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Search for more effective isolates and use patterns for B.t. Systematically evaluate augmentation of parasites and predators. Survey endemic parasites and predators (foreign explorations).

6. ARS laboratories involved (present)

   Savannah, GA; Manhattan, KS; Brownsville, TX

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   None.

9. Suggested ARS contact individual(s) - (Key person)

   W. McGaughey
   H. Dulmage
   R. Arbogast

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cryptolestes spp.

2. Candidate biocontrol agents (when known and appropriate)

   Xylocoris flavipes, *Pyemotes tritici*

3. Commodities

   Grain

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Systematically evaluate augmentation of parasites and predators. Survey endemic parasites and predators (foreign explorations).

6. ARS laboratories involved (present)

   Savannah, GA

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   None.

9. Suggested ARS contact individual(s) - (Key person)

   R. Arbogast

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Oryzaephilus surinamensis — Sawtoothed grain beetle

2. Candidate biocontrol agents (when known and appropriate)

   Xylocoris flavipes, *Pyemotes tritici*

3. Commodities

   Grain; groundnuts; dried fruits; cereal products; tree nuts

4. Status of biocontrol research effort:

   a. Past: Laboratory tests for pest suppresion.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Systematically evaluate augmentation of parasites and predators. Survey endemic parasites and predators and conduct foreign explorations if native natural enemies do not prove satisfactory.

6. ARS laboratories involved (present)

   Savannah, GA

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   None.

9. Suggested ARS contact individual(s) - (Key person)

   R. Arbogast

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Tribolium spp. — Flour beetles

2. Candidate biocontrol agents (when known and appropriate)

   Xylocoris flavipes, *Pyemotes tritici*

3. Commodities

   Grain; groundnuts; dried fruit; cereal products; tree nuts

4. Status of biocontrol research effort:

   a. Past: Laboratory tests for pest suppression

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Systematically evaluate augmentation of parasites and predators. Survey endemic parasites, predators, and pathogens. Conduct foreign explorations if native biological control agents are not successful.

6. ARS laboratories involved (present)

   Savannha, GA

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   None.

9. Suggested ARS contact individual(s) - (Key person)

   R. Arbogast

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Carpophilus spp. — Dried frui

2. Candidate biocontrol agents (when known and appr

   Entomogenous nematodes and fungi.

3. Commodities

   In field control and control on harvested and dr

4. Status of biocontrol research effort:

   a. Past: Small scale evaluations of several reduction in the field.

   b. Present: None.

5. Recommended research approaches (augmentati other).

   Isolate, identify and evaluate endemic bio not useful for augmentation or manipulatio be done.

6. ARS laboratories involved (present)

   Fresno

7. Other Federal laboratories involved (pres

   None.

8. Potential State/University cooperatic

   None.

9. Suggested ARS contact individual(s)

   P. Vail

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and

    4.3.01.1.d; 4.3.01.1.j

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

   Grapholita molesta | Oriental fruit moth (quarantine insect)

2. Candidate biocontrol agents (when known and appropriate)

   No known candidates

3. Commodities

   Stone fruits

4. Status of biocontrol research effort:

   a. Past: Little effort.

   b. Present: Little effort.

5. Recommended research approaches (augmentation and introduction of predators and parasites; isolation and use of insect pathogens.

   Survey of existing natural enemies and pathogens. Evaluation of existing natural enemies. Foreign exploration and evaluation if warranted.

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   University of California

9. Suggested ARS contact individual(s) - (Key person)

   P. Vail
   A. K. Burditt

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Anarsia lineatella — Peach twig borer (quarantined insect)

2. Candidate biocontrol agents (when known and appropriate)

   No known candidates

3. Commodities

   Stone fruits and tree nuts

4. Status of biocontrol research effort:

   a. Past: Little effort.

   b. Present: Little effort.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Survey of existing natural enemies and pathogens. Evaluation of existing natural enemies and pathogens. Foreign exploration and evaluation if warranted.

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   Univ. of CA

9. Suggested ARS contact individual(s) - (Key person)

   P. Vail
   A. K. Burditt

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.01.1.d

PRIORITIES SUMMARY F.

Chairman: Ralph Bram

Team Members: David Dame, Robert Faust, Robert Harris, Edward F. Knipling, Paul Marsh, Richard Miller, Richard Patterson, Katherine Reichelderfer, Jack Seawright, and Al Undeen

I. Problem Title:

Insects Affecting Man and Animals

II. Problem Statement:

Insects, ticks, and mites cause considerable livestock loss and human suffering primarily through biting, irritation, and the spread of diseases in the U.S. and other parts of the world. Losses in animal productivity from these pests are estimated to be annually in excess of $3 billion in the U.S. alone, which is about 5% of the total income from animal agriculture. The current technology used to reduce these arthropod pest populations to acceptable levels is the application of chemical insecticides and acaricides. The continued use of these chemicals presents a number of problems such as chemical resistance in pest populations, the toxicity to animals and people, hazards to the environment, and public opposition to area-wide spraying. Although the use of chemicals will, for the present time, be the main tool for control, it is imperative that research be intensified to develop alternative methods. One research area that needs further investigation is the role that biological control agents such as parasites, predators, pathogens, and competitors may play in reducing these pests to acceptable levels. Examples of research that have shown a certain degree of success in the livestock area include the use of hymenopterous parasites to control the house fly and the stable fly around livestock and poultry complexes and, in the area of insects affecting man, the use of the pathogen Bacillus thurinigiensis (H-14) and a mermithid nematode to control mosquitoes. Because of the ability of these pests to disperse widely, programs to assess specific biocontrol techniques will require adequate resources for large-scale testing.

III. Criteria for Priorities:

a. Economic importance
b. Domestic (National) or international need
c. Cost effectiveness of current control
d. Potential impact of biocontrol agents
e. Usefulness in coordinated IPM strategies
f. Taxonomic information available
g. User acceptability
h. Time required for implementation
i. Environmental concerns

IV. List of Priorities:

1. Stable fly - house fly - filth fly complex (especially *Stomoxys calcitrans* and *Musca domestica*)
2. Mosquitoes (particularly *Culex* spp., *Anopheles* spp., *Aedes* spp., and *Psorophora* spp.)
3. Horn fly (*Haematobia irritans*)
4. Face fly (*Musca autumnalis*)
5. Black flies (Simuliidae)
6. Cockroaches (Blattidae)
7. Fire ants (*Solenopsis* spp.)
8. Biting flies (Tabanidae, Ceratopogonidae)
9. Eye gnats (*Hippelates* spp.)
10. Ticks (Ixodidae, Argasidae)
11. Cattle grubs (*Hypoderma* spp.)
12. Tsetse flies (*Glossina* spp.)
13. Kissing bugs (Triatomidae)
14. Fleas (Siphonaptera)
15. Sheep Keds (Hippoboscidae)
16. Lice (Anoplura, Mallophaga)
17. Mites (Acarina)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism

Pest organism	Common name
Stomoxys calcitrans L., Musca domestica, other filth breeding muscoid flies	stable flies, houseflies and other filth breeding flies

2. Candidate biocontrol agents (when known and appropriate)

Numerous parasites: Spalangia sp., Muscidifurax sp., Pachycrepoideus sp. Tachineaphagus sp., Nasonia sp., Trichopria sp., etc. Predators: beetles of the families Staphylinidae and Histeridae; Pathogens: Bacillus moritae, B. thuringiensis (exotoxin)

3. Commodities

Livestock, humans

4. Status of biocontrol research effort:

a. Past: Survey made of native parasites and predators which attack muscoid flies.

b. Present: Augmented releases made of selected parasites to control muscoid flies. Research done on predators-parasite-host interrelationship.

5. Recommended research approaches (augmentation, introduction, pathology, other).

More research needed on interrelationship of host-parasite-predator-pathogen interrelationship under different ecological conditions. Develop selected strains of parasites, predators and pathogens that will be effective under various environmental conditions. Field studies on the efficacies of these natural enemies of flies. Foreign exploration for more efficient parasites and predators.

6. ARS laboratories involved (present)

Insects Affecting Man & Animals Laboratory, Midwest Livestock Insects Laboratory, Livestock Insects Lab., MD.

7. Other Federal laboratories involved (present/future)

None.

8. Potential State/University cooperation

Cornell University (NY), University of California (Riverside) and North Carolina State University

9. Suggested ARS contact individual(s) - (Key person)

R. S. Patterson

10. Funds required

$1,050,000

11. SY input needed

7 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

3.5.03.1.e
3.5.04.1.e

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Culicidae (Culex, Anopheles, Aedes, Psorophora — Mosquitoes

2. Candidate biocontrol agents (when known and appropriate)

Microsporidia, nematodes, microturbellarian flatworms, bacteria, Toxorhynchites, Laegenidium, mosquito fish

3. Commodities

Livestock, man

4. Status of biocontrol research effort:

a. Past: Extensive exploration, variety of laboratory and limited field evaluations; successful research in field with Bacillus thuringiensis (Bt14), Romanomermis culicivorax, Toxorhynchites rutilus, Tx. amboinensis, Laegenidium giganteum, mosquito fish.

b. Present: Further experimentation and development of Bacillus sphaericus, Culicinomyces clavosporus, Tolypocladium cylindrosporum and development of initiatives.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Development of propagation technology for predators and parasites and extension of knowledge on population dynamics and host/natural enemy interactions.

Determination of complex life cycle of microsporida and fungal organisms. Genetic manipulations for enhanced capability of natural enemies. Determination of optimum usage in coordinated IPM activity.

6. ARS laboratories involved (present)

Insects Affecting Man and Animals Research Laboratory, Gainesville, Florida

Gulf Coast Mosquito Research Laboratory, Lake Charles, Louisiana

7. Other Federal laboratories involved (present/future)

CDC (San Juan, PR; Fort Collins, CO; Atlanta, GA)

8. Potential State/University cooperation

S-122, SR Regional Research Program on Riceland Mosquitoes (Expt. stations in Arkansas, California, Louisiana, Mississippi, and Texas Univ. Florida, N. C. State, Notre Dame Univ., etc.

9. Suggested ARS contact individual(s) - (Key person)

   D. A. Dame

10. Funds required

    $900,000

11. SY input needed

    6 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    3.5.03.1.e
    3.5.04.1.f

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

<u>Haematobia irritans</u> — horn fly

2. Candidate biocontrol agents (when known and appropriate)

Predators such as beetles of the families Staphylinidae and Histeridae, beetle predators, dung-burying scarab beetles Hymenopterus parasites of immature horn flies

3. Commodities

Cattle (beef and dairy)

4. Status of biocontrol research effort:

   a. Past: Faunistic surveys of dung breeding insects have been conducted in Missouri, California, and Texas. Horn fly mortality factors have been identified in Missouri. These studies indicate that predator beetles are the most important biological agent present. Studies in Texas indicate that about 90% mortality of horn flies result from the action of beneficial insects. Dung-burying scarabs have been investigated in Texas, California, and Australia.

   b. Present: Faunistic surveys of dung inhabiting arthropods are being conducted in Minnesota and Georgia. Studies are being conducted in Texas and Australia to determine effect of scarabs, parasites, and predators on horn fly reproduction. The effectiveness of <u>Bacillus thuringiensis</u> (Bti) on horn fly larvae is being determined.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Conduct a search of Africa and/or Asia for specific parasites, predators, and pathogens of the immature stages of the horn fly.

Determine habitat requirements for beneficial insects that inhabit cattle droppings and develop techniques to modify the habitat to improve effectiveness of the beneficial insects.

Determine if ruminant bacteria can be genetically engineered to produce a toxin or metabolite that will inhibit horn fly development.

6. ARS laboratories involved (present)

VTERL, ARS, College Station, Texas

7. Other Federal laboratories involved (present/future)

U.S. Livestock Insect Lab, Kerrville, Texas
Insects Affecting Man and Animals Research Lab, Gainesville, FL

8. Potential State/University cooperation

University of Minnesota
University of Georgia
Texas A&M University
University of California at Davis
University of Missouri
University of Nebraska

9. Suggested ARS contact individual(s) - (Key person)

R. L. Harris
VTERL-ARS
P.O. Box G.E.
College Station, Texas 77841

10. Funds required

$750,000

11. SY input needed

5 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

3.5.03.1.e

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Musca autunmalis DeGeer — face fly

2. Candidate biocontrol agents (when known and appropriate)

Aleochara bimaculata - staphylinid
Aleochara tristis - staphylinid
Heterolylenchus autumnalis - nematode
Ravinia herminiere - diptera
Alysia ribibunda - braconidae
Aphaereta pallipes - braconidae
Eucoila impatiens - cynipidae
Muscidifurax raptor - pteromalidae
Xyalophora quinquelineata - hymenoptera

3. Commodities

cattle, horses

4. Status of biocontrol research effort:

a. Past: above candidate biocontrol agents have been identified as parasites or predators of the face fly. Parasitism rate has generally been low. *Aleochara tristis* was introduced into the U.S. from Europe, but was not effective in controlling face flies.

b. Present: At the present time there is little or no work on biological control of the face fly being conducted in U.S.

5. Recommended research approaches (augmentation, introduction, pathology, other).

There should be additional foreign exploration to find possible parasites or predators of the face fly in Europe. If any are found they should be reared in the laboratory and released to see if they would become established in the U.S. Additional tests with sarcophagids should be conducted to determine their potential for reducing face fly populations. New pathogens need to be tested as feed-through compounds for control of larvae in the manure.

6. ARS laboratories involved (present)

Livestock Insects Laboratory
Beltsville, Maryland

Midwest Livestock Insects Laboratory
Lincoln, Nebraska

7. Other Federal laboratories involved (present/future)

   Possible federal quarantine facility

8. Potential State/University cooperation

   Cornell University
   University of Missouri
   University of Kentucky

9. Suggested ARS contact individual(s) - (Key person)

   R. W. Miller
   Beltsville, Maryland

10. Funds required

   $300,000

11. SY input needed

   2

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

   3.5.03.1.e
   3.5.04.1.a
   3.5.04.1.c

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cnephia spp. — black flies
   Simulium spp.
   Prosimulium sp.

2. Candidate biocontrol agents (when known and appropriate)

   Bacillus thuringiensis var. *israelensis*, "ovarian phycomycete" mermithid nematodes, Microsporidia

3. Commodities

   humans, livestock

4. Status of biocontrol research effort:

   a. Past: memithidae, *Neoaplectana*, *B. thuringiensis* var. *israelensis* (Bti) all tested in the field and lab, only Bti was effective

   b. Present: *B. thuringensis* var. *israelensis*

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Microbial insecticides, augmentation of the fungal pathogen, basic research into fungal and microsporidia life cycles.

6. ARS laboratories involved (present)

   Insects Affecting Man and Animals Research Laboratory

7. Other Federal laboratories involved (present/future)

   Undetermined

8. Potential State/University cooperation

   Penn. State; University of California, Riverside; Cornell Univ., U. Michigan; West Virginia St. University

9. Suggested ARS contact individual(s) - (Key person)

   A. H. Undeen

10. Funds required

    $300,000

11. SY input needed

    2

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    3.5.03.1.e

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Blatella germanica, Periplaneta sp. — German cockroaches, cockroaches

2. Candidate biocontrol agents (when known and appropriate)

   Various parasites, predators and pathogens

3. Commodities

   human, household, stored products and bulk grain storage

4. Status of biocontrol research effort:

   a. Past: Very little biocontrol except for survey of a few parasites of cockroaches.

   b. Present: Survey of parasites of the brown banded cockroach and the American cockroach in the U.S. Limited study on pathogens of cockroaches.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Foreign exploration for potential parasites in Africa and Europe. Survey made of pathogens of cockroaches. Augment releases of parasites to control cockroaches in the field. Survey of potential predators of cockroach that would be acceptable.

6. ARS laboratories involved (present)

   1 (0.05 SY) Insects Affecting Man and Animals Laboratory, Gainesville, Florida

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   North Carolina State University, University of California (Riverside)

9. Suggested ARS contact individual(s) - (Key person)

   R. S. Patterson

10. Funds required

   $300,000

11. SY input needed

    2 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    3.5.03.1.e

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

<u>Solenopsis invicta</u> — Red Imported Fire Ant

2. Candidate biocontrol agents (when known and appropriate)

   Unknown.

3. Commodities

   Man, animal, soybean, citrus, vegetable crops

4. Status of biocontrol research effort:

   a. Past: The past effort has been very limited, and no significant usable biocontrol agents have been identified.

   b. Present: The present effort consists of a project aimed at discovering biocontrol agents in the native homeland (Brazil and Argentina) of <u>S. invita</u>.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Since the search for biocontrol agents has just begun, the work will necessarily be of an exploratory nature in the survey of natural populations for parasites, predators, and pathogens. The types of biocontrol agents that are found will be evaluated for their suitability for augmentation, introduction, or combination with other methods in an IPM approach.

6. ARS laboratories involved (present)

   Insects Affecting Man and Animals Laboratory, Gainesville, Florida.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   University of Florida
   Texas A&M University
   University of Georgia

9. Suggested ARS contact individual(s) - (Key person)

   C. F. Lofgren

10. Funds required

    $600,000

11. SY input needed

    4 SY's

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    3.5.05.1.C

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

Pest organism	Common name
Tabanidae, Ceratopogonidae	horse flies, deer flies, biting midges

2. Candidate biocontrol agents (when known and appropriate)

   A fungus in Tabanus, some microsporidia

3. Commodities

   livestock, humans

4. Status of biocontrol research effort:

   a. Past: Infectivity and pathogenity of the fungal pathogen has been demonstrated.

   b. Present: None presently have been actively studied as biocontrol agents.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Larval habitats are not very amendable for treatment with biocontrol agents. Search for additional pathogen and parasites is needed.

6. ARS laboratories involved (present)

   Insects Affecting Man and Animals Research Lab. (Ceratopogonidae)

7. Other Federal laboratories involved (present/future)

   Arthropod-Born Aerial Diseases Laboratory, Denver, Colorado

8. Potential State/University cooperation

   University of Florida, Georgia Southern University, North Carolina State University

9. Suggested ARS contact individual(s) - (Key person)

   D. L. Kline

10. Funds required

   $600,000

11. SY input needed

    4

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    3.5.03.1.e

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Hippelates pusio — eye gnat

2. Candidate biocontrol agents (when known and appropriate)

   Unknown

3. Commodities

   Man and animals

4. Status of biocontrol research effort:

   a. Past: No significant work has been done.

   b. Present: Currently, there is no active project on *H. pusio*.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Surveys should be conducted on natural populations to identify pathogens, predators, and parasites.

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

   Undetermined.

8. Potential State/University cooperation

   University of California (Riverside); West Florida Arthropod Research Laboratory (Panama City)

9. Suggested ARS contact individual(s) - (Key person)

   R. A. Bram

10. Funds required

    $150,000

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    3.5.03.1.e

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Glossina species — Tsetse flies

2. Candidate biocontrol agents (when known and appropriate)

   Hymenopteran pupal parasites (Syntomophyrum spp., Mutilla spp., Pteromalidae), possibly bacteria and nematodes.

3. Commodities

   Livestock, man

4. Status of biocontrol research effort:

   a. Past: Limited to exploration for natural enemy incidence, plus 1 release study with parasites in 1930's.

   b. Present: No active programs.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction of pteromalid pupal parasites and augmentation of indigenous parasites. Determination of life cycles, natural history, and host/natural enemy interaction. Development of propagation technology.

6. ARS laboratories involved (present)

   Limited to non-biocontrol research at: Insects Affecting Man and Animals Research laboratory, Gainesville, Florida

7. Other Federal laboratories involved (present/future)

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8. Potential State/University cooperation

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9. Suggested ARS contact individual(s) - (Key person)

   R. A. Bram
   D. A. Dame

10. Funds required

   $450,000/year

11. SY input needed

3 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

3.5.03.1.e
3.5.04.1.f

PRIORITIES SUMMARY G.

Chairman: George Papavizas

Team Members: Peter Adams, William Ayers, Edwin Civerolo, Chester Howell, Jack Lewis, Robert Lumsden, and James Marois

I. Problem Title:

Soilborne Diseases of Plants

II. Problem Statement:

Of the more than 1,200 genera of plants listed in the U.S. Dept. of Agriculture Agricultural Handbook 165 (1960), 655 are host to 3,330 root diseases. About 91% of the 2,000 principal diseases of the 31 principal crops of the U.S.A. have been determined to be root diseases or enter the plant through the root system (Wilson, 1968). Soilborne pathogens of crops cause approximately 50% of the total estimated annual losses of economic crops due to plant diseases (James, 1981). A gross breakdown of annual losses due to soilborne diseases would be (in billions of dollars), oilseed crops, 1.0; grains, 0.8; vegetables 0.6; cotton, sugar crops and tobacco, 0.9; forage/pasture crops 0.2; ornamentals and nursery crops, 0.2; and fruit and specialty crops, 0.05. Since most of the damage to plants by soilborne diseases is below ground, or results from underground infections, crop losses from such diseases are greatly underestimated. These diseases are also confused with symptoms of mineral deficiencies, poor fertility, soil moisture excess, drought, or other causes.

Few soilborne diseases can be controlled by using genetic resistance. Fungicides and fumigants are used to some extent. However, the pesticides, many of which have been placed on the EPA's list for deregistration, cause adverse environmental effects. Other disadvantages are their expense, their sometimes lack of efficacy, development of resistance to pesticides, and the energy needed for their production. Because of these constraints, biological control is gaining stature as a potential method for soilborne disease control. Despite the growing recognition of the importance of biological control, research and development to suppress soilborne plant pathogens, in fact all plant pathogens, has been underfunded and the state-of-the-art of biocontrol is fragmented. With the exception of Peniophora gigantea and Agrobacterium radiobacter (developed outside the U.S.) registered for biological control of Fomes rot of forest trees and crown gall, respectively, we do not have in the U.S. any registered biocontrol agents that are formulated specifically for plant disease control. ARS can and should assume leadership in biocontrol technology. Recent research in a few ARS laboratories has shown great potential for biological control of this major group of plant pathogens.

III. Criteria for Priorities:

	Weight
Commodity	7
Economic importance of pest	6
U.S. distribution of problem	5

Effectiveness of current control techniques	-2
Degree of control required	-2
Potential for control by biological agents	10
Expertise	2

IV. List of Priorities:

	Pathogen	Total score	Total SY's* required
1.	*Pythium* spp.	270	2.0
2.	*Verticillium* spp.	268	2.0
3.	*Sclerotinia* spp.	260	2.0
4.	*Fusarium* spp.	254	2.0
5.	*Rhizoctonia solani*	250	2.0
6.	*Cochliobolus* spp.	214	2.0
7.	*Sclerotium rolfsii*	184	2.0
8.	*Gaeumannomyces graminis*	181	2.0
9.	*Phytophthora* spp.	149	2.0
10.	*Phymatotrichum omnivorum*	149	2.0
11.	*Macrophomina phaseolina*	147	1.0
12.	*Colletotrichum* spp.	136	1.0
13.	*Armillaria mellea*	133	1.0
14.	*Sclerotium cepivorum*	122	1.0
15.	*Cylindrocladium* sp.	108	0.5
16.	*Thielaviopsis basicola*	98	1.0
17.	*Aphanomyces* spp.	48	0.5
			26.0

* Includes 8 existing SYs

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Pythium spp. — Damping-off

2. Candidate biocontrol agents (when known and appropriate)

   Gliocladium, *Penicillium*, *Trichoderma*, *Laetisaria*, *Pseudomonas*, *Pythium*

3. Commodities

   All crops

4. Status of biocontrol research effort:

   a. Past:

   b. Present: In progress

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Soilborne Diseases Lab, National Cotton Pathology Research Lab, Cereal Disease Lab, USDA at Prosser, Cereal Pathology at Prosser

7. Other Federal laboratories involved (present/future)

   Iowa State
   Florist and Nursery Crops Lab

8. Potential State/University cooperation

   Many

9. Suggested ARS contact individual(s) - (Key person)

   R. D. Lumsden, J. Kraft, C. R. Howell

10. Funds required

    $500,000

11. SY input needed

    2.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	10	70
Economic importance of pathogen	6	10	60
U.S. geographic distribution	5	10	50
Effectiveness of present controls	-2	10	-20
Degree of control required	-2	5	-10
Potential for biological control	10	10	100
Expertise	2	10	20
	Total		270

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

<u>Verticillium</u> spp. — Wilt

Pest organism	Common name
Verticillium spp.	Wilt

2. Candidate biocontrol agents (when known and appropriate)

   Talaromyces, *Pseudomonas*

3. Commodities

   cotton, potato, alfalfa, tomato, ornamentals, maple, mint, pistachio, avocado, olive trees, eggplant, pepper, hops

4. Status of biocontrol research effort:

   a. Past:

   b. Present: In progress

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Soilborne Diseases Lab, National Cotton Pathology Research Lab, USDA at Davis, USDA at Prosser

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   Many

9. Suggested ARS contact individual(s) - (Key person)

   C. R. Howell
   G. C. Papavizas

10. Funds required

    $500,000

11. SY input needed

    2.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	8	56
Economic importance of pathogen	6	10	60
U.S. geographic distribution	5	10	50
Effectiveness of present controls	-2	4	- 8
Degree of control required	-2	5	-10
Potential for biological control	10	10	100
Expertise	2	10	20
	Total		268

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

   Sclerotinia spp. | Sclerotinia rot

2. Candidate biocontrol agents (when known and appropriate)

   Sporidesmium, _Teratosperma_, _Talaromyces_, _Gliocladium_

3. Commodities

   All dicots and some monocots

4. Status of biocontrol research effort:

   a. Past:

   b. Present: In progress

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Soilborne Diseases Lab, PPI
   Peanut Lab, Holland, VA

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   Many

9. Suggested ARS contact individual(s) - (Key person)

   P. B. Adams
   R. D. Lumsden

10. Funds required

    $500,000

11. SY input needed

    2.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	8	56
Economic importance of pathogen	6	8	48
U.S. geographic distribution	5	10	50
Effectiveness of present controls	-2	3	- 6
Degree of control required	-2	4	- 8
Potential for biological control	10	10	100
Expertise	2	10	20
	Total		260

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Fusarium spp. — Wilt and rot

2. Candidate biocontrol agents (when known and appropriate)

   Penicillium, *Fusarium*, *Gliocladium*, *Trichoderma*, *Bacillus*, *Sphaenonaemella*, *Trichothecium*, *Gonatobotrys*, *Chaetomium*

3. Commodities

   All crops

4. Status of biocontrol research effort:

   a. Past:

   b. Present: In progress

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Cereal Lab USDA at Prosser, Soilborne Diseases Lab., USDA at Iowa State, Florist and Nursery Crops Lab.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   Univ. Minnesota
   Many other institutions

9. Suggested ARS contact individual(s) - (Key person)

   R. J. Cook

10. Funds required

    $500,000

11. SY input needed

    2.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	10	70
Economic importance of pathogen	6	10	60
U.S. geographic distribution	5	10	50
Effectiveness of present controls	-2	5	-10
Degree of control required	-2	3	- 6
Potential for biological control	10	7	70
Expertise	2	10	20
	Total		254

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

Rhizoctonia solani | Root rot and damping-off

2. Candidate biocontrol agents (when known and appropriate)

Trichoderma, Gliocladium, Laetisaria, Dendrostilbella, Pseudomonas, Talaromyces

3. Commodities

All crops

4. Status of biocontrol research effort:

a. Past:

b. Present: In progress

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

Soilborne Diseases Lab.
National Cotton Lab, Florist and Nursery Crops Lab.

7. Other Federal laboratories involved (present/future)

None.

8. Potential State/University cooperation

Many

9. Suggested ARS contact individual(s) - (Key person)

G. C. Papavizas

10. Funds required

$500,000

11. SY input needed

2.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	10	70
Economic importance of pathogen	6	10	60
U.S. geographic distribution	5	10	50
Effectiveness of present controls	-2	5	-10
Degree of control required	-2	5	-10
Potential for biological control	10	8	80
Expertise	2	10	20
	Total		250

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cochliobolus spp. — Root rot, Foot rot

2. Candidate biocontrol agents (when known and appropriate)

   Sphaeronaemella, amoebae

3. Commodities

   Grains, grasses

4. Status of biocontrol research effort:

   a. Past:

   b. Present: No work at present

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   USDA Lab at Ames

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   Iowa State, Univ. of Minnesota
   University of Nebraska

9. Suggested ARS contact individual(s) - (Key person)

   N. Vakili

10. Funds required

    $500,000

11. SY input needed

    2.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	6	42
Economic importance of pathogen	6	7	42
U.S. geographic distribution	5	8	40
Effectiveness of present controls	-2	1	- 2
Degree of control required	-2	4	- 8
Potential for biological control	10	8	80
Expertise	2	10	20
	Total		214

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism	Common name
Sclerotium rolfsii	Rot, blight

2. Candidate biocontrol agents (when known and appropriate)

   Trichoderma, *Gliocladium*

3. Commodities

   All crops

4. Status of biocontrol research effort:

   a. Past: Some

   b. Present: In progress

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Soilborne Diseases Lab.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   Many

9. Suggested ARS contact individual(s) - (Key person)

   G. C. Papavizas

10. Funds required

    $500,000

11. SY input needed

    2.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	7	49
Economic importance of pathogen	6	6	36
U.S. geographic distribution	5	5	25
Effectiveness of present controls	−2	4	− 8
Degree of control required	−2	4	− 8
Potential for biological control	10	7	70
Expertise	2	10	20
	Total		184

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Gaeumannomyces graminis — Take-all

2. Candidate biocontrol agents (when known and appropriate)

   Pseudomonas, *Phialophora*

3. Commodities

   Grains

4. Status of biocontrol research effort:

   a. Past: Some work

   b. Present: In progress

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Cereal Lab, Pullman

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   Washington State Univ.
   Purdue Univ.

9. Suggested ARS contact individual(s) - (Key person)

   R. J. Cook

10. Funds required

    $500,000

11. SY input needed

    2.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	7	49
Economic importance of pathogen	6	3	18
U.S. geographic distribution	5	2	10
Effectiveness of present controls	-2	4	- 8
Degree of control required	-2	4	- 8
Potential for biological control	10	10	100
Expertise	2	10	20
	Total		181

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Phytophthora spp. — Rot, Blight

2. Candidate biocontrol agents (when known and appropriate)

   Actinomycetes, Hyphochytrium, Aspergillus

3. Commodities

   Vegetables, ornametals, fruit trees

4. Status of biocontrol research effort:

   a. Past: Some

   b. Present: No work at present

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   ----

9. Suggested ARS contact individual(s) - (Key person)

   G. C. Papavizas

10. Funds required

    $500,000

11. SY input needed

    2.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	7	49
Economic importance of pathogen	6	7	42
U.S. geographic distribution	5	8	40
Effectiveness of present controls	-2	3	- 6
Degree of control required	-2	3	- 6
Potential for biological control	10	2	20
Expertise	2	5	10
	Total		149

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Phymatotrichum omnivorum — Texas root rot

2. Candidate biocontrol agents (when known and appropriate)

   Gliocladium

3. Commodities

   Cotton and many other crops

4. Status of biocontrol research effort:

   a. Past:

   b. Present: No work at present

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   Texas A&M

9. Suggested ARS contact individual(s) - (Key person)

   C. R. Howell

10. Funds required

    $500,000

11. SY input needed

    2.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	10	70
Economic importance of pathogen	6	8	48
U.S. geographic distribution	5	3	15
Effectiveness of present controls	-2	1	- 2
Degree of control required	-2	5	-10
Potential for biological control	10	2	20
Expertise	2	4	8
	Total		149

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Macrophomina phaseolina — Charcoal rot

2. Candidate biocontrol agents (when known and appropriate)

   Mycorrhizal fungi, Stachybotrys

3. Commodities

   Soybean, bean, tobacco, cotton, corn, ornamentals, vegetables

4. Status of biocontrol research effort:

   a. Past:

   b. Present: No work at present

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   ----

9. Suggested ARS contact individual(s) - (Key person)

   J. C. Locke

10. Funds required

    $250,000

11. SY input needed

    1.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	5	35
Economic importance of pathogen	6	5	30
U.S. geographic distribution	5	6	30
Effectiveness of present controls	-2	5	-10
Degree of control required	-2	5	-10
Potential for biological control	10	7	70
Expertise	2	1	2
	Total		153

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Sclerotium cepivorum — White rot

2. Candidate biocontrol agents (when known and appropriate)

   Sporidesmium, *Coniothyrium*, *Trichoderma*

3. Commodities

   Allium spp.

4. Status of biocontrol research effort:

   a. Past:

   b. Present: No work at present

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Soilborne Diseases Lab.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   Rutgers Univ., Cornell
   Washington State

9. Suggested ARS contact individual(s) - (Key person)

   P. B. Adams

10. Funds required

    $250,000

11. SY input needed

    1.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	2	14
Economic importance of pathogen	6	4	24
U.S. geographic distribution	5	2	10
Effectiveness of present controls	-2	5	-10
Degree of control required	-2	8	-16
Potential for biological control	10	8	80
Expertise	2	10	20
	Total		122

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cylindrocladium sp. — Black rot, brown root rot

2. Candidate biocontrol agents (when known and appropriate)

   None

3. Commodities

   Peanuts, beans, potato, sweet potato, corn, jute, tomato, watermelon, ornamentals, soybeans, walnut seedlings

4. Status of biocontrol research effort:

   a. Past:

   b. Present: No work at present

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   -----

9. Suggested ARS contact individual(s) - (Key person)

   -----

10. Funds required

    $125,000

11. SY input needed

    0.5

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	3	21
Economic importance of pathogen	6	6	36
U.S. geographic distribution	5	3	15
Effectiveness of present controls	-2	1	- 2
Degree of control required	-2	3	- 6
Potential for biological control	10	4	40
Expertise	2	2	4
	Total		108

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Thielaviopsis basicola — Black root rot

2. Candidate biocontrol agents (when known and appropriate)

   None

3. Commodities

   Cotton, tobacco, peanuts, beans, holly

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   Texas A&M
   New Mexico State Univ., VPI

9. Suggested ARS contact individual(s) - (Key person)

   G. C. Papavizas

10. Funds required

    $250,000

11. SY input needed

    1.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	4	28
Economic importance of pathogen	6	4	24
U.S. geographic distribution	5	6	30
Effectiveness of present controls	-2	2	- 4
Degree of control required	-2	5	-10
Potential for biological control	10	1	10
Expertise	2	10	20
	Total		98

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Aphanyomyces sp. — Root rot, Black root

2. Candidate biocontrol agents (when known and appropriate)

   Hyphochytrium

3. Commodities

   Pea, beet

4. Status of biocontrol research effort:

   a. Past:

   b. Present: No work at present.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

   None.

8. Potential State/University cooperation

   -----

9. Suggested ARS contact individual(s) - (Key person)

   J. A. Lewis

10. Funds required

    $125,000

11. SY input needed

    0.5

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.02.1.R

13. Criteria

	Weight	Score	W x S
Commodity	7	2	14
Economic importance of pathogen	6	2	12
U.S. geographic distribution	5	2	10
Effectiveness of present controls	-2	1	- 2
Degree of control required	-2	5	-10
Potential for biological control	10	2	20
Expertise	2	2	4
	Total		48

PRIORITIES SUMMARY H.

Chairman: Harvey Spurr

Team Members: Merrit Nelson, Guy Knudsen, and Amy Rossman

I. Problem Title:

Foliar Plant Pathogens: Biological Control of Diseases of Aerial Plant Parts

II. Problem Statement:

Diseases of aerial plant parts are a major source of loss to all commodities. Current control practices are not always effective, economically sound, or environmentally safe. Support for research on biological control of disease on aerial plant parts has been extremely limited; however, the results to date suggest there is considerable potential for this strategy. Thus, the development of biological control for aerial plant parts is needed to augment and improve the level of disease control.

III. Criteria for Priorities:

Criteria	Weight
a. Commodity	5
b. Economic importance of disease	3
c. Geographic distribution	1
d. Effectiveness and acceptability of current control	5
e. Level of control acceptable	5
f. Potential for biological control	4
g. Potential as model for biological control	4

(1 = low; 5 = high)

IV. List of Priorities:

Prioritization of research on the biological control of diseases of aerial plant parts has not been satisfactorily achieved at this time. The "Information Summary for Each Target Pest for ARS Biological Control Program" is incomplete. The format is based upon biological control research with insects and weeds. It does not organize information in a manner compatible with the "state-of-the-art". Prioritization of diseases on a commodity basis has been achieved earlier for loss assessment purposes. Therefore, prioritization for biological control of diseases of aerial plant parts should be made by selecting examples to serve as model systems for basic research. These will serve to develop and expand the research approaches. The recommmended research approaches for most of the pathogens/diseases are similar and include the following elements: development of detection and identification

procedures, development of information on the microbial ecology of plant surfaces (phylloplane), development of knowledge of the nature and basis of these interactions, and development of methodology to control or augment these interactions under field conditions.

a. Fungal Pathogens:

1. *Helminthosporium carbonum*
2. *Puccinia graminis*
3. *Peronospora tabacina*, *Plasmopora viticola*
4. *Podosphaera* spp.
5. *Botrytis cinerea*
6. *Monilinia fructicola*
7. *Uromyces phaseoli*
8. *Ceratocystis ulmi*, *C. fagacearum*
9. *Alternaria alternata*, *A. solani*
10. *Tilletia caries*, *Ustilago maydis*
11. *Cercosporidium personatum*
12. *Venturia inaequalis*
13. *Colletotrichum gloeosporioides*
14. *Phomopsis sojae*

b. Bacterial Pathogens:

1. Leaf spot diseases: *Pseudomonas syringae* pv[s] *phaseolicola*, *glycinea*
   Xanthomonas campestris pv[s] *pruni*, *vesicatoria*, *malvacearum*
2. Fireblight disease: *Erwinia amylovora*
3. Frost damaging (ice nucleation active) bacteria:
   Erwinia herbicola
   Pseudomonas syringae pv. *syringae*
4. Canker diseases: *Pseudomonas syringae* pv. *syringae*
5. Soft-rot diseases: *Erwinia carotovora*
6. Diseases caused by *Corynebacterium* species

c. Viral and Fastidious Prokaryote Pathogens:

1. Citrus tristiza virus
2. *Spiroplasma citri*
3. Tomato ringspot virus
4. Tobacco mosaic virus
5. Barley yellow dwarf virus

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Helminthosporium carbonum — Corn leaf blight

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Puccinia graminis — Wheat stem rust

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   University of Montana (Gene Sharp)

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

Pest organism	Common name
Peronospora tabacina	Tobacco blue mold
Plasmopora viticola	Grape downy mildew

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present: H. W. Spurr, Jr. - Oxford, NC (Tobacco blue mold)
   Jim Marois - University of California-Davis (Grape downy mildew)

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   University of California, Davis

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Podosphaera spp. — Apple powdery mildew

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Corvallis, Oregon

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Cornell University, Geneva, NY

9. Suggested ARS contact individual(s) - (Key person)

   Duane Coyier

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Botrytis cinerea — Onion leaf blight, Strawberry gray mold

2. Candidate biocontrol agents (when known and appropriate)

   Pseudomonas cepacia, *P. fluorescens*

3. Commodities

4. Status of biocontrol research effort:

   a. Past: Newhook, 1957, antagonistic fungi; Blakeman & Fraser, 1971, antagonistic bacteria.

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Cornell University (J. Lorbeer)

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Monilinia fructicola — Peach brown rot

2. Candidate biocontrol agents (when known and appropriate)

   Pseudomonas spp., Bacillus spp.

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present: Larry Pusey, Charlie Wilson

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Byron, GA; Kearneysville, WV

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   L. Pusey
   C. Wilson

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Uromyces phaseoli — Bean rust

2. Candidate biocontrol agents (when known and appropriate)

   Bacillus subtilis

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present: C. J. Baker, Beltsville, MD

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Beltsville, MD

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   C. J. Baker

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

Pest organism	Common name
Ceratocystis ulmi	Dutch elm disease
C. fagacearum	Oak wilt

2. Candidate biocontrol agents (when known and appropriate)

   Pseudomonas syringae

3. Commodities

4. Status of biocontrol research effort:

   a. Past: G. Strobel (Montana) injection of *P. syringae* into elms.

   b. Present: R. Campana (University of Maine) injection of *P. syringae* into elms.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   University of Maine (R. Campana)

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Pest organism	Common name
Alternaria alternata	Tobacco brown spot
A. solani	Tomato early blight

2. Candidate biocontrol agents (when known and appropriate)

   Pseudomonas cepacia, *Bacillus thuringiensis*, avirulent *Alternaria alternata*

3. Commodities

4. Status of biocontrol research effort:

   a. Past: H. W. Spurr, Jr.

   b. Present: H. W. Spurr, Jr., G. R. Knudsen - Oxford, NC

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Pest organism	Common name
Tilletia caries	Wheat bunt
Ustilago maydis	Corn smut

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Cercosporidium personatum — Peanut leafspot

2. Candidate biocontrol agents (when known and appropriate)

   Bacillus thuringiensis, *Pseudomonas cepacia*

3. Commodities

4. Status of biocontrol research effort:

   a. Past: H. W. Spurr, Jr.

   b. Present: H. W. Spurr, Jr.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Oxford, NC

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Venturia inaequalis — Apple scab

2. Candidate biocontrol agents (when known and appropriate)

   Pseudomonas spp., unidentified bacteria

3. Commodities

4. Status of biocontrol research effort:

   a. Past: 1968: Crosse *et al*: Microfloral management of fallen leaves. 1965: Leben *et al*: Applied antagonistic bacteria.

   b. Present: J. Andrews, University of Wisconsin, Madison

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   J. Andrews, University of Wisconsin, Madison

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

   Colletotrichum gloeosporiodes | Anthracnose

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Phomopsis sojae — Soybean leafspot

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Xanthomonas campestris pvs *pruni*, *vesicatoria*, *malvacearum* & *Pseudomonas syringae* pvs *phaseolicola*, *glycinea* — Bacterial fruit & leaf spots, blights

2. Candidate biocontrol agents (when known and appropriate)

Bacteriophages, *Erwinia herbicola*, *Bacillus* spp.

3. Commodities

Prunus spp., tomato, pepper, cotton, beans

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Univerity of California, Davis, Berkeley
   Cornell University
   Michigan State University
   Oklahoma State University

9. Suggested ARS contact individual(s) - (Key person)

   E. L. Civerolo, H. W. Spurr, Jr., A. W. Saettler

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Erwinia amylovora — Fireblight

2. Candidate biocontrol agents (when known and appropriate)

   Erwinia herbicola, Bacteriophages

3. Commodities

   Apple, pear

4. Status of biocontrol research effort:

   a. Past:

   b. Present: Some work at State university locations using *E. herbicola* to control infection of flowers by *E. amylovora*.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Cornell, University, S. V. Beer

9. Suggested ARS contact individual(s) - (Key person)

   T. Van der Zwet
   E. L. Civerolo

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism	Common name
Erwinia herbicola *Pseudomonas syringae* pv. *syringae*	Ice-nucleation active bacteria

2. Candidate biocontrol agents (when known and appropriate)

   Non-INA strains of the bacteria

3. Commodities

   Corn, citrus, potatoes, others

4. Status of biocontrol research effort:

   a. Past:

   b. Present: S. Lindow, (Berkeley) - "engineered" antagonists. Hirano & Upper (Wisconsin) - epidemiology of INA's.

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation •

   S. Lindow (Berkeley), S. Hirano (Wisconsin)

9. Suggested ARS contact individual(s) - (Key person)

   C. Upper (Wisconsin)

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Pseudomonas syringae pv. *syringae* — Canker disease

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   Prunus spp.

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

   Erwinia carotovora | Soft-rot disease

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   Several vegetables and fruits

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Beltsville, MD

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   H. Moline, J. Wells

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Corynebacterium spp. — Bacterial ring rot

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   Potatoes

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Citrus tristeza virus — Quick decline of citrus

2. Candidate biocontrol agents (when known and appropriate)

   Mild, avirulent strains

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Hort. Res. Lab., Orlando, FL

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   University of California, Riverside

9. Suggested ARS contact individual(s) - (Key person)

   S. Garnsey

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Sprioplasma citri — Citrus stubborn disease

2. Candidate biocontrol agents (when known and appropriate)

   Viruses

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   R. E. Davis

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism	Common name
Tomato ringspot virus	Prunus stem pitting disease

2. Candidate biocontrol agents (when known and appropriate)

   Mild strains

3. Commodities

   Prunus spp.

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

   Appalachian Fruit Tree Research Station, Keaneysville, WV

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Cornell University

9. Suggested ARS contact individual(s) - (Key person)

   R. Scorza

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

Pest organism	Common name
Tobacco mosaic virus	Tobacco mosaic virus

2. Candidate biocontrol agents (when known and appropriate)

   Avirulent, attenuated, mild strains

3. Commodities

   Tomato, tobacco.

4. Status of biocontrol research effort:

   a. Past:

   b. Present: Cross protection and induced resistance

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   J. Kuc, University of Kentucky
   NCSU - G. V. Gooding

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Barley yellow dwarf virus — Barley yellow dwarf virus

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

4. Status of biocontrol research effort:

   a. Past:

   b. Present:

5. Recommended research approaches (augmentation, introduction, pathology, other).

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   H. W. Spurr, Jr.

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

PRIORITIES SUMMARY I.

Chairman: Charles Wilson

Team Members: Harold Moline and John Wells

I. Problem Title:

Biocontrol of plant pathogens causing post-harvest diseases.

II. Problem Statement:

Post-harvest diseases cause 20 to 30 percent losses of our harvested food. These losses are particularly devastating because of the high dollar value of harvested crops and the resulting limitations of food exports. Post-harvest diseases of crops present additional hazards by their introduction of mycotoxins and pesticide residues into the food chain of man and other animals.

We rely primarily on chemicals to control post-harvest pathogens. In a number of cases we do not have adequate control of these diseases at all. Present chemical control procedures are rendered less effective because of increased concerns over the use of pesticides on our food and of the development of resistance by pathogens to pesticides.

The climate is right for the development of non-pesticide means of controlling post-harvest diseases. Public demand for more wholesome food gives added emphasis to this need. Recent successes with the control of brown rot of peaches and soft rot of potatoes using antagonistic bacteria show the feasibility of the biological control of post-harvest diseases. Accelerated research in this area should yield a number of new biocontrol procedures for additional post-harvest diseases. Since this is an unexplored area, a need exists for the development of basic information on the ecological interactions of pathogen, host, biocontrol agent, and storage environments. A higher degree of success is expected for biocontrol in storage than under field conditions because of our greater ability to control environmental conditions.

III. Criteria for Priorities:

(1) Distribution, (2) economic value of crop, (3) epidemic potential, (4) state-of-the-art

IV. List of Priorities:

(High)

1.	Penicillium (a) expansum	world-wide distribution,
	(b) digitatum	high losses, broad host range,
	(c) italicum	high value comodity
2.	Aspergillus (a) flavus	feed grains & nuts, toxigenic

(b) parasiticus

3.	Botrytis cinerea	world-wide distribution, wide host range, high losses
4.	Monilinia fructicola laxa	world-wide distribution, major major pathogen of stone fruits
5.	Rhizopus stolonifer	world-wide distribution, broad host range
6.	Erwinia carotovora	world-wide distribution, high losses
	amylovora	potential quarantine pest
	atroseptica	state-private sector research
	chrysanthemi	progress on biocontrol U of MA

(Medium-High)

7.	Fusarium spp	world-wide, soil-borne pathogen, wide host range
8.	Geotrichum candidum	world-wide, citrus & other hosts high losses
9.	Alternaria spp.	world-wide, broad host range, economic importance moderate
10.	Phytophthora infestans	world-wide, single major crop epidemic potential high

(Medium)
Cladosporium, Pythium, Sclerotinia, Botrospheria, Colletotrichum, Pseudomonas, Diplodia, Glomerella, Mucor, Myrotheciam, Rhizopus oryzae

(Low)
There are many other fungal and bacterial pathogens that cause loss to vegetables in storage, transit, and the market place. Some cause minor losses on a broad range of commodities, other more severe losses on minor commodities or under specific conditions. They include mildews, rusts, anthracnose, and rotting organisms. They are listed here by genus:

Albugo
Alternaria
Armillaria
Ascochyta
Aspergillus
Botrytis
Bremia
Cephalosporium
Cephalothecium
Ceratocystis
Cercospora
Chaanephora
Cladosporium
Colletotrichum
Cornybacterium
Diaporthe
Erwinia
Erysiphe
Fusarium
Geotrichum

Heterosporium
Itersonilia
Macrophomina
Marssonia
Monilochaetis
Mucor
Mycosphaerella
Nematospora
Oospora
Pellicularia
Penicillium
Peronospora
Phoma
Phyllosticta
Phymatotrichum
Phytophthora
Plasmopara
Plenodomus
Pseudomonas
Puccinia
Pyrenochaeta
Pythium
Rhizoctonia
Rhizopus
Septoria
Stemphylium
Streptomyces
Sclerotinia
Spongospora
Trichoderma
Thielaviopsis
Urocystis
Uromyces
Verticillium
Vylaria
Xanthomonas

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

<u>Penicillium expansum</u> — blue mold

2. Candidate biocontrol agents (when known and appropriate)

None known

3. Commodities

stone fruits, pome fruits, small fruits, figs

4. Status of biocontrol research effort:

a. Past: None.

b. Present: Preliminary studies on blue mold of apple and pears are being conducted at AFRS Kearneysville by Dr. Wojciech Janisewicz

5. Recommended research approaches (augmentation, introduction, pathology, other).

(1) present program should be augmented; (2) post harvest treatments with antagonists tested; (3) studies on mechanisms.

6. ARS laboratories involved (present)

ARS Appalachian Fruit Research Laboratory, Kearneysville, W.V.

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

Dr. Wojciech Janisewicz, Appalachian Fruit Research Laboratory

10. Funds required

$150,000

11. SY input needed

1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

4.3.02.1.b
4.3.02.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

<u>Penicillium digitatum</u> — green mold

2. Candidate biocontrol agents (when known and appropriate)

None known

3. Commodities

citrus

4. Status of biocontrol research effort:

a. Past: None.

b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

(1) screen for antagonists; (2) develop post harvest treatments with antagonists; (3) determine mechanism of action.

6. ARS laboratories involved (present)

None.

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

University of California, Florida, Texas A&M

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

$150,000

11. SY input needed

1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

4.3.02.1.b
4.3.02.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Penicillium italicum — blue mold on citrus

2. Candidate biocontrol agents (when known and appropriate)

   not known

3. Commodities

   citrus

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   (1) screen for antagonists; (2) develop post harvest treatments with antagonists; (3) determine mechanisms of action.

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

    $150,000

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.02.1.b
    4.3.02.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Aspergillus flavus

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   grains and nuts

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   (1) screen for antagonists; (2) develop post harvest treatments with antagonists; (3) determine mechanisms of action.

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

    $150,000

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.02.1.b
    4.3.02.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Botrytis cinerea — gray mold

2. Candidate biocontrol agents (when known and appropriate)

   Trichoderma and bacteria

3. Commodities

   stone fruits, pome fruits, small fruits, citrus, ornamental bulbs

4. Status of biocontrol research effort:

   a. Past: *Trichoderma* has shown effectiveness on grapes and strawberries

   b. Present: Antagonistic bacteria are being tested at the Appalachian Fruit Research Station on pome and small fruits.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   (1) screen for antagonists; (2) develop post harvest treatments with antagonists; (3) determine mechanisms of action.

6. ARS laboratories involved (present)

   USDA Appalachian Fruit Research Laboratory, Kearneysville, W.V.

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   Dr. Wojciech Janisewicz, Appalachian Fruit Research Station

10. Funds required

    $150,000

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.02.1.b
    4.3.02.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Monilinia fruticola and laxa — brown rot

2. Candidate biocontrol agents (when known and appropriate)

   Bacillus spp.

3. Commodities

   stone fruits, pome fruits

4. Status of biocontrol research effort:

   a. Past: An effective biocontrol for brown rot of peaches has been developed using Bacillus subtilis.

   b. Present: This procedure is being pilot tested in the Eastern U.S.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   (1) screen for antagonists; (2) develop post harvest treatments with antagonists; (3) determine mechanism of action.

6. ARS laboratories involved (present)

   Appalachian Fruit Research Station and Southeastern Fruit and Nut Laboratory, Byron

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Cornell University

9. Suggested ARS contact individual(s) - (Key person)

   Charles L. Wilson, AFRS and P. Larry Pusey, Byron Ga.

10. Funds required

    $150,000

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.02.1.b
    4.3.02.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Rhizopus stolonifer — Rhizopus rot

2. Candidate biocontrol agents (when known and appropriate)

   antagonistic bacteria

3. Commodities

   pome fruit, stone fruit, small fruit

4. Status of biocontrol research effort:

   a. Past: Antagonistic bacteria have been found at the Appalachian Fruit Research Station.

   b. Present: Screening for antagonists is being conducted at the Appalachian Fruit Research Station.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   (1) screen for antagonists; (2) develop post harvest treatments with antagonists; (3) determine mechanism of action.

6. ARS laboratories involved (present)

   USDA Appalachian Fruit Research Laboratory

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   Charles L. Wilson, Appalachian Fruit Research Station

10. Funds required

    $150,000

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.02.1.b
    4.3.02.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Erwinia spp. — soft rots

2. Candidate biocontrol agents (when known and appropriate)

antagonistic bacteria

3. Commodities

vegetables, ornamental bulbs and corns

4. Status of biocontrol research effort:

a. Past: Researchers at the University of Mass. have been able to control soft rot of potato with an antagonistic bacterium.

b. Present: ARS New Brunswick, N.J. lab is contemplating research in this area.

5. Recommended research approaches (augmentation, introduction, pathology, other).

(1) screen for antagonists; (2) develop post harvest treatments with antagonists; (3) determine mechanism of action.

6. ARS laboratories involved (present)

ARS New Brunswick post harvest laboratory

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

University of Massachusetts

9. Suggested ARS contact individual(s) - (Key person)

John Wells, ARS New Brunswick, N.J. Laboratory

10. Funds required

$150,000

11. SY input needed

1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

4.3.02.1.b
4.3.02.1.b

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Fusarium spp. — Fusarium brown rot

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   citrus

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   (1) screen antagonists; (2) develop post harvest treatments with antagonists; (3) determine mechanism of action.

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

    $150,000

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.02.1.b
    4.3.02.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   <u>Geotrichum candidum</u>

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   citrus and other hosts

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   (1) screen for antagonists; (2) develop post harvest treatments with antagonists; (3) determine mechanism of action.

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

    $150,000

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.02.1.b; 4.3.02.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

   Alternaria spp. | *Alternaria* rot

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   pome fruits, stone fruits, citrus

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   (1) screen for antagonists; (2) develop post harvest treatments with antagonists; (3) determine mechanism of action.

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

   Wojciech Janisewicz, USDA Appalachian Fruit Research Station

10. Funds required

    $150,000

11. SY input needed

    1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.02.1.b
    4.3.02.1.d

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Phytophthora infestans — late blight

2. Candidate biocontrol agents (when known and appropriate)

   antagonistic bacteria

3. Commodities

   potato

4. Status of biocontrol research effort:

   a. Past: None.

   b. Present: None.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   (1) screen for antagonists; (2) develop post harvest treatments with antagonists; (3) determine mechanisms of action.

6. ARS laboratories involved (present)

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    4.3.02.1.b
    4.3.02.1.d

PRIORITIES SUMMARY J.

Chairman: Burt Endo

Team Members: Bill Brodie, William Dowler, George Fassuliotis, Ray Rebois, Robin Huettel, Rodrigo Rodriguez-Kabana, Richard Sayre, and Joe Sasser

1. Title:

Rationale for Evaluating Current and Projected Research to Develop Biological Control of Plant-Parasitic Nematodes.

2. Problem Statement:

Although considerable progress has been made during the last three decades in development of control strategies for plant-parasitic nematodes, annual losses of food and fiber crops to these pests are in excess of $5 B. Conventional approaches to nematode control, such as breeding for resistance and crop rotation, have not been effective in reducing these losses to acceptable levels. While breeding for resistance is a valuable tool for control, there are too few crop plants with satisfactory sources of resistance. In some cases, after successive plantings in infested fields, crop plants lose their resistance because new biological strains of the nematode emerge. Crop rotation can be effective against certain target nematode species. However, crop rotation systems often require additional equipment investments and/or use of less profitable crops which are not economically desirable. The discovery and wide scale use of nematicides that began in the mid-1940's and early 1950's and continued until recently had greatly minimized crop losses, especially on high value per acre crops, such as citrus, potatoes, peaches, pineapple, and where crop losses were high on major crops such as corn, soybeans, and cotton. Chemical control is generally too costly to use on many crops of low value/acre crops such as small grains. Even so, there has been wide acceptance on the part of growers to use nematicides, because in many instances crops could not be grown profitably without them.

In 1977, the first of several effective and widely used nematicides, DBCP, was taken off the market because of its effect on sperm counts of males working with this material. This was the beginning of the cancellation or restricted use of a number of effective nematicides that included aldicarb, ethylene dibromide, carbofuran, oxamyl, D-D and other compounds that also face future ban because of their carcinogenic properties. These losses have placed enormous constraints on our ability to develop effective long-term strategies for control of plant destructive nematodes.

Biological control has not been used widely for nematode control and it is believed that this may be due to the lack of resources and research personnel directed towards its exploitation as a control measure. Several potential biocontrol organisms have been identified that appear effective against the root knot, soybean cyst and other nematodes. With this encouraging prospect of success in the use of biological agents and the added constraints on bans imposed on several of the most effective nematicides, it is timely and urgent to develop biocontrol agents to fill the void created through the withdrawal of nematicides.

3. General Criteria for Priorities:

a. Twenty major genera and/or species of plant parasitic nematodes were prioritized by the following general criteria as potential targets for biocontrol agents.

   1. Crop losses attributed to nematode genera and/or species: These nematodes listed are of national importance as they cause an estimated annual loss of $5-6,000,000,000 on field and vegetable crops, fruit and nut trees, and ornamentals.

   2. Efficacy of controls: Current control practices are not always satisfactory or have been removed from use due to EPA deregulation. For example, several nematicides have been deregulated recently (EDB, DBCP). Several others have been associated with ground water contamination and can, therefore, be considered at risk (aldicarb, carbofuran, oxamyl, D-D). Resistant varieties are not always satisfactory due to development of resistance breaking biotypes, single species resistant cultivars or the unavailability of new varieties for a particular geographic region. Crop rotation is not always economically acceptable to the grower. Changes in tillage practices (i.e., no-tillage, minimum tillage, legume cover crops to prevent erosion, and monoculture) will substantially increase nematode problems.

   3. Association with other organisms: Several natural antagonists have been associated with these nematode genera and/or species. Actual biocontrol potential of natural antagonists have been demonstrated.

   4. Growers acceptance of control measures: Adoption of biocontrol as an alternative to conventional control has gained acceptance among growers. Environmental awareness and concern for public health problems have greatly contributed to the acceptance of biocontrol systems.

   5. Survival of biocontrol agents: Some biocontrol agents can become self-perpetuating and substantially reduce the cost of control of nematodes.

b. In addition to the above considerations that were used to designate the 20 major economically important plant-parasitic nematode genera and/or species, the following specific criteria were weighted to prioritize the ten* most important genera/species on the list:

1. Number and types of crops affected
2. Relative losses that could be expected without use of chemicals due to nematodes
3. Geographic distribution
4. Relative annual input cost to control nematodes
5. Acceptability of current control measures for long-term
6. Known biocontrol agents and/or the probability of finding natural antagonists
7. Likelihood of scientific success with biocontrol
8. Likelihood of widescale adoption by growers
9. State-Private Sector -- current/planned research
10. Likelihood of congressional support

4. List of Priorities:

			*Criteria rating (0-100)
1.	Meloidogyne incognita	southern root-knot nematode	81
2.	Heterodera glycines	soybean cyst nematode	80
3.	Globodera rostochiensis	golden cyst nematode	69
4.	M. javanica	Japanese root-knot nematode	68
5.	M. arenaria	peanut root-knot nematode	67
6.	Pratylenchus penetrans	root lesion nematode	57
7.	M. hapla	northern root-knot nematode	56
8.	Tylenchulus semipenetrans	citrus nematode	56
9.	Rotylenchulus reniformis	reniform nematode	53

10.	*H. shachtii*	sugarbeet cyst nematode 50
11.	*P. brachyurus*	root lesion nematode
12.	Ring nematode	ring nematode
13.	*M. chitwoodi*	Columbia root-knot nematode
14.	*H. avenae*	cereal cyst nematode
15.	*Xiphinema* spp.	dagger nematode
16.	*H. zeae*	corn cyst nematode
17.	*M. naasi*	barley root-knot nematode
18.	*P. coffeae*	coffee root lesion nematode
19.	*Radopholus* spp.	burrowing nematode
20.	*P. scribneri*	root lesion nematode

The following is a list of other nematodes genera/species considered economically important:

21.	*P. agilis*	root lesion nematode
22.	*P. vulnus*	root lesion nematode
23.	*Belonolaimus* spp.	sting nematode
24.	*Hoplolaimus* spp.	lance nematode
25.	*Helicotylenchus* spp.	spiral nematode
26.	*Paratylenchus* spp.	pin nematode
27.	*Bursaphelenchus xylophilus*	pinewood nematode
28.	*Longidorus*	needle nematode
29.	*Ditylenchus* spp.	stem and bulb nematode

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Meloidogyne spp. — root knot nematodes

2. Candidate biocontrol agents (when known and appropriate) (BCA)

   Bacillus penetrans
   Paecilomyces lilacinus
   Verticillium spp.
   Dactylella spp.
   Fusarium spp.
   Catenaria spp.
   Arthrobotrys spp.
   Myzocytium spp.
   Streptomyces (avermictin)

3. Commodities

   Multiple economic crops

4. Status of biocontrol research effort:

   a. Past:

   b. Present: Preliminary promising results

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Identify BCA's, test pathogenicity.
   Methods of cultivation of BCA.
   Greenhouse, field test
   Small demonstration tests.

6. ARS laboratories involved (present)

   Beltsville - 1 SY

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Auburn, AL - R. R.-Kabana
   Riverside, CA - R. Mankau
   Gainesville, FL - G. C. Smart
   Raleigh, NC - J. N. Sasser

9. Suggested ARS contact individual(s) - (Key person)

   R. M. Sayre
   R. V. Rebois

10. Funds required

$300,000

11. SY input needed

2 SY's

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.03.1e Problem: Technology is inadequate for controlling nematodes on crops with maximum effectiveness, efficiency, safety and economy.

Subproblem e. Knowledge about soil organisms that are natural enemies of nematodes is lacking and limits the development and use of these organisms as a means of control.

2.4.02.1.0t.
2.4.05.1.a, b, c, d, e, f, g, h, i, j

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Heterodera glycines — soybean cyst nematode

2. Candidate biocontrol agents (when known and appropriate) (BCA)

   Nematophthora gynophila
   Paecilomyces lilacinus
   Verticillium spp.
   Fusarium spp.
   Dactylella spp.
   Catenaria spp.
   Myrothecium verrucaria
   Chaetomium cochliodes
   Acrostalagmus abovatus
   Gliocladium catenulatum

3. Commodities

   soybeans

4. Status of biocontrol research effort:

   a. Past:

   b. Present: Preliminary promising results.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Identify BCA's, test pathogenicity.
   Methods of cultivation of BCA.
   Greenhouse, field test.
   Small demonstration tests.

6. ARS laboratories involved (present)

   Beltsville, MD - 0.1
   Jackson, TN - 0.1

7. Other Federal laboratories involved (present/future)

   Raleigh, NC - J. N. Sasser
   Fayetteville, AR - R. Riggs
   Auburn, AL - R. R.-Kabana

8. Potential State/University cooperation

   Same as #7, others will be considered.

9. Suggested ARS contact individual(s) - (Key person)

   Beltsville - R. M. Sayre and R. V. Rebois
   Jackson, TN - L. D. Young

10. Funds required

$300,000 (5 years)

11. SY input needed

2 SY's

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.03.1e
2.4.05.1i

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Globodera rostochiensis — golden cyst nematode

2. Candidate biocontrol agents (when known and appropriate) (BCA)

   Paecilomyces lilacinus
   Catenaria spp.
   Verticillium spp.
   Fusarium spp.
   Unknown

3. Commodities

   potato

4. Status of biocontrol research effort:

   a. Past: None

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Identify BCA's, test pathogenicity.
   Methods of cultivation of BCA.
   Greenhouse, field test.
   Small demonstration tests.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   Ithaca, New York

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

    $150,000 (5 years)

11. SY input needed

1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.03.1e
2.4.05.1c

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   <u>Globodera rostochiensis</u> — golden cyst nematode

2. Candidate biocontrol agents (when known and appropriate) (BCA)

   <u>Paecilomyces lilacinus</u>
   <u>Catenaria</u> spp.
   <u>Verticillium</u> spp.
   <u>Fusarium</u> spp.
   Unknown

3. Commodities

   potato

4. Status of biocontrol research effort:

   a. Past: None

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Identify BCA's, test pathogenicity.
   Methods of cultivation of BCA.
   Greenhouse, field test.
   Small demonstration tests.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   Ithaca, New York

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

    $150,000 (5 years)

11. SY input needed

1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.03.1e
2.4.05.1c

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Pratylenchus spp. — root lesion nematodes
P. penetrans
P. scribneri
P. brachyurus
P. vulnus
P. coffeae
P. agilis
P. hexincisus

2. Candidate biocontrol agents (when known and appropriate) (BCA)

Bacillus penetrans
Catenaria spp.
Trapping fungi

3. Commodities

corn, citrus, potato, soybeans, corn, peanuts, fruit and nut crops, vegetables, forage, turf, ornamentals

4. Status of biocontrol research effort:

   a. Past:

   b. Present: Preliminary results promising.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Identify BCA's, test pathogenicity.
Methods of cultivation of BCA.
Greenhouse, field test.
Small demonstration tests.

6. ARS laboratories involved (present)

None

7. Other Federal laboratories involved (present/future)

None

8. Potential State/University cooperation

Several

9. Suggested ARS contact individual(s) - (Key person)

R. M. Sayre and R. V. Rebois

10. Funds required

5 years

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.03.1e
2.4.05.1a, b, c, d, e, h, i

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Pest organism	Common name
Tylenchulus semipenetrans	citrus nematode
Rotylenchulus reniformis	reniform nematode

2. Candidate biocontrol agents (when known and appropriate) (BCA)

Bacillus penetrans
Paecilomyces lilacinus

3. Commodities

citrus, cotton, veg. crops, olives, pineapple, soybean

4. Status of biocontrol research effort:

a. Past:
b. Present: Preliminary

5. Recommended research approaches (augmentation, introduction, pathology, other).

Identify BCA's, test pathogenicity.
Methods of cultivation of BCA.
Greenhouse, field test.
Small demonstration tests.

6. ARS laboratories involved (present)

None

7. Other Federal laboratories involved (present/future)

None

8. Potential State/University cooperation

California, Texas, Maryland, Florida

9. Suggested ARS contact individual(s) - (Key person)

R. N. Huettel and R. M. Sayre

10. Funds required

5 years

11. SY input needed

1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Pest organism	Common name
Heterodera spp.	cyst nematodes
H. schachtii	sugar beet nematode
H. avenae	cereal cyst nematode
H. zeae	corn cyst nematode

2. Candidate biocontrol agents (when known and appropriate) (BCA)

   Fusarium spp.
   Nematophthora gynophilus
   Trapping fungi
   Acremonium strictum
   Verticillium spp.
   Nematophagus azerbaidzhanicus

3. Commodities

   sugar beets, crucifers, cereal, corn

4. Status of biocontrol research effort:

   a. Past:

   b. Present: preliminary results promising

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Identify BCA's, test pathogenicity.
   Methods of cultivation of BCA.
   Greenhouse, field test.
   Small demonstration tests.

6. ARS laboratories involved (present)

   Beltsville, MD - 0.1 SY

7. Other Federal laboratories involved (present/future)

   Past: Riverside, CA (Van Gundy) *H. schachtii*

8. Potential State/University cooperation

   Various: Riverside, CA; College Park, MD - L. Krusberg

9. Suggested ARS contact individual(s) - (Key person)

   R. V. Rebois and R. M. Sayre

10. Funds required

$150,000 (5 years)

11. SY input needed

1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.03.1e
2.4.05.1d, f, g

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Pest organism	Common name
Ectoparasitic nematodes - over 300 species	
Xiphinema spp.	needle nematode
Trichodorus spp.	stubby root nematode
Ring nematode group	ring nematode
Belonolaimus spp.	sting nematode
Helicotylenchus spp.	spiral nematode
Hoplolaimus spp.	lance nematode
Tylenchorhynchus spp.	stunt nematode

2. Candidate biocontrol agents (when known and appropriate) (BCA)

Bacillus penetrans
trapping fungi
Catenaria spp.

3. Commodities

peaches, grapes, turf, fruit & nut crops, soybeans, corn, potatoes, peanuts, citrus, forage, and others.

4. Status of biocontrol research effort:

a. Past:
b. Present: Preliminary results promising.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Identify BCA's, test pathogenicity.
Methods of cultivation of BCA.
Greenhouse, field tests.
Small demonstration tests.

6. ARS laboratories involved (present)

Tifton, GA - A. Nyczepir

7. Other Federal laboratories involved (present/future)

Clemson, CS - S. A. Lewis, G. C. Zehr
Gainesville, FL - R. P. Esser

8. Potential State/University cooperation

Same as 7 plus others

9. Suggested ARS contact individual(s) - (Key person)

R. M. Sayre and G. Fassuliotus

10. Funds required

$300,000 (5 years)

11. SY input needed

2 SY's

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.03.1e
2.4.05.1a to j

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Bursaphelenchus xylophilus — pine wood nematode

2. Candidate biocontrol agents (when known and appropriate)

   unknown

3. Commodities

   pine trees

4. Status of biocontrol research effort:

   a. Past: None

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Survey for BCA's.
   Evaluate BCA's if found.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   Various

9. Suggested ARS contact individual(s) - (Key person)

10. Funds required

    (5 years)

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

PRIORITIES SUMMARY K.

Chairman: Richard Soper

Team Members: Richard Dysart, Marjorie Hoy, James Kelleher, Phyllis Martin, Martin Shapiro, Robert Anderson, and Bill Metterhouse

I. Problem Title:

Insects on Ornamentals, Shade Trees, and Forests

II. Problem Statement:

The use of chemical insecticides on ornamentals and shade trees raises public concern of possible health hazards because of the possibility of contact by humans and domestic animals. For this reason the EPA has limited the use of many insecticides making them unavailable for use around habitations. In addition, the development of insecticide resistance is another major concern. Alternative control methods are needed.

Forest insect control has several important considerations. Higher insect damage can be tolerated in forests than on crops. This lends itself to the concept of biocontrol where a residual host population is required to maintain a reservoir of pathogens predators or parasitoids. A major problem for pathogens considered for use as insecticides is the development of more effective formulation and application technology.

Because of the vast acreage involved in forest pest infestations, material and application costs become a limiting factor in the use of chemical insecticides. However, since some pathogens such as fungi, viruses and protozoa may have carry-over control for several years, the higher costs for application can be justified.

The use of silivicultural practice with biological control agents i.e. pathogens, parasites, and predators, should be considered in an integrated control approach since these methods may well be complementary.

III. Criteria for Priorities:

a. Economic or aesthetic importance of pest.
b. National, regional, or local importance.
c. Pest of native, introduced, or unknown origin.
d. Effectiveness of current control techniques.
e. Degree of damage reduction by biological control.
f. Potential control by biological agents.

g. Extent of prior attempts at biological control
h. Availability of expertise.
i. Availability of biocontrol agents.
j. Type of biological control agents and strategies
    - pathogens
    - predators
    - parasitoids
    - augmentation
    - inundation
    - inoculative release

IV. List of Priorities:

It is the recommendation of this committee that these priorities be re-examined periodically to insure that they are still relevant.

ORNAMENTALS AND SHADE TREE

Priority	Scientific	Common
1.	Lymantria dispar (L)	gypsy moth
2.	Pyrrhalta luteola (Muller)	elm leaf beetle
3.	Pseudaulacaspis pentagona (Targioni-Tozzetti)	white peach scale
4.	Otiorhynchus sulcatus (F.)	black vine weevil
5.	Thyridopreryx ephemeraeformis (Haworth)	bagworm
6.	Fenusa pusilla	birch leaf miner
7.	Scolytus multistriatus	smaller European elm bark beetle
8.	Tetranychus urticae (Koch)	two spotted spider mite

FOREST

1.	Choristoneura occidentalis (Freeman)	western spruce budworm
2.	Choristoneura fumiferana (Clements)	spruce budworm
3.	Lymantria dispar (L.)	gypsy moth
4.	Fiorinia externa (Ferris)	elongate hemlock scale
5.	Matsucoccus resinosae (Bran &. Godwin)	red pine scale
6.	Alsophila pometaria (Harris)	fall cankerworm
7.	Paleacrita vernata (Peck)	spring cankerworm
8.	Malacosoma disstria (Hubner)	forest tent caterpillar
9.	Reticulitermes spp.	termites
10.	Orgyia pseudotsugata	Douglas-fir tussock moth
11.	Rhyacionia frustrana (Comstock)	Nantucket pine tip moth
12.	Coleophora laricella (Hubner)	larch case bearer
13.	Hylobius pales (Herbst)	pales weevil
14.	Dendroctonus frontapis (Zimmerman)	southern pine beetle
15.	Dendroctonus ponderosae (Hopkins)	Mountain pine beetle
16.	Archips semiferana (Walker)	oak leaf roller
17.	Diprion similis (Hartig)	introduced pine sawfly
18.	Neodiprion sertifer (Geoffy)	European pine sawfly

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

Pest organism	Common name
Lymantria dispar (L.)	Gypsy moth (GM)

2. Candidate biocontrol agents (when known and appropriate)

   Parasite complex existing in North America

3. Commodities

   Forest and Shade Trees

4. Status of biocontrol research effort:

   a. Past: As a result of previous importation efforts, 10 parasites and one predator are established in the U.S.

   b. Present: Recent efforts to establish additional species of natural enemies in the U.S. have been unsuccessful. Although the established natural enemies have undoubtedly had some effect on retarding or reducing the severity of GM outbreaks, cyclic outbreaks still occur with troublesome regularity.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   In order to prevent gypsy moth outbreaks, there is a need to develop the means to utilize parasites as reguators in low level (endemic) gypsy moth populations. To develop and implement any strategy (e.g., augmentation) aimed at doing this, we must find out which parasite species offer the greatest potential for use at low host densitites. Therefore, a study is needed to relate the incidence of parasitism by the various species in the parasite complex to host density and other ecological variables. This type of study requires a long term commitment (3-4 years), but is likely to yield results of lasting, fundamental value.

6. ARS laboratories involved (present)

   Beneficial Insects Research Laboratory (BIRL)
   501 South Chapel Street
   Newark, Delaware 19713

7. Other Federal laboratories involved (present/future)

   Otis Methods Development Center
   Otis Air National Guard Base
   Massachusetts 02542

8. Potential State/University cooperation

New Jersey Department of Agriculture
Trenton, New Jersey

Other research organizations have also expressed interest.

9. Suggested ARS contact individual(s) - (Key person)

Roger W. Fuester, BIRL

10. Funds required

$166,900 (Oct. 1, 1984 - Sept. 30, 1986)

11. SY input needed

1.0

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

Develop fundamental principles of biological control for insect pests, especially strategies useful in preventing outbreaks of gypsy moth and other cyclic defoliators.

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Lymantria dispar (L.) — Gypsy Moth

2. Candidate biocontrol agents (when known and appropriate)

   Parasites *Asiphona samarensis* (Villeneuve) and Parasites in Far East

3. Commodities

   Forest and Shade Tree

4. Status of biocontrol research effort:

   a. Past: This tachinid was first recovered from *L. dispar* in Austria by myself and others during the 1970's, but was very rare.

   b. Present: CIBC studies of endemic populations of *L. dispar* in Alsace showed it to be the dominant tachinid with parasitism rates of 45% in 4th and 5th instars. Several areas in Far East have not been explored sufficiently.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   This species has never been released in North America. Introduction attempts should be made during 1984-1986.

6. ARS laboratories involved (present)

   Asian Parasite Laboratory (APL), Seoul, Korea
   Beneficial Insects Research Laboratory (BIRL), Newark, Delaware

7. Other Federal laboratories involved (present/future)

   European Parasite Laboratory, Sevres, France.

7a. Foreign Cooperating Organization: Commonwealth Inst. Bioc., Delemont, Switzerland.

8. Potential State/University cooperation

   Maryland IPM Project
   N.J. Dept. Agric.
   Penna. Bureau Forestry
   Conn. Agric. Exp. Sta.

9. Suggested ARS contact individual(s) - (Key person)

   Roger W. Fuester (BIRL)

10. Funds required

$1,080,000 (April 1, 1984 - March 30, 1987)

11. SY input needed

9.0 SY (3 SY x 3 yr.)

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.1.3.1a: Approach Element: Collect, evaluate preserve, and distribute germplasm of ... beneficial organisms ... that are valuable in pest management programs. Problem: Many ... pests have foreign origins; these and the beneficial organisms that are their natural enemies must be studied abroad and the beneficial organisms introduced and established or heavy ... losses will continue. Subproblem a: Collections and evaluations of benefiial parasites, predators, and pathogens for arthropod control are inadequate to meet the needs of crop protection strategies.

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Lymantria dispar — Gypsy Moth

2. Candidate biocontrol agents (when known and appropriate)

   Entomophaga aulicae (fungus)

3. Commodities

   Forest and Shade Trees

4. Status of biocontrol research effort:

   a. Past: An NP virus has been registered by U.S. Forest Service but has not reached a truly commercial status. B.t. is effective but considered rather expensive.

   b. Present: The pathogen E. aulicae is well documented in the Japanese literature as causing collapse of the gypsy moth in that country. An effort was made in 1907-08 to introduce this pathogen in the U.S. Although the fungus was not cultured nor a successful introduction made, the investigators lost their gypsy moth colony to the pathogen.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Although gypsy moth has been researched in the United States for many decades, E. aulicae has never been detected. Since gypsy moth was brought into this country without this pathogen, it may be possible to use the "introduction" approach. If not, technology exists which might be adapted to produce a "mycoinsecticide" for this fungus.

6. ARS laboratories involved (present)

   Insect Pathology Research Unit
   Boyce Thompson Institute
   Cornell University
   Ithaca, NY 14583

7. Other Federal laboratories involved (present/future)

   Center for Biological Control of Northeastern Forest
   Insects and Diseases
   Northeastern Forest Experiment Station
   51 Mill Pond Road
   Hamden, CT 06514

7a. Foreign cooperating organization (present):

Forestry and Forest Products Research Institute
P.O. Box 16
Tsukuba-Norin-Kenkyu-Danchi
Ibaraki 305
Japan

8. Potential State/University cooperation

Unknown at this time.

9. Suggested ARS contact individual(s) - (Key person)

Dr. Richard S. Soper

10. Funds required

$50,000 (June 1, 1984 - August 30, 1985)

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.1.3: Expand foreign exploration and research, including cooperative research with foreign scientists and organizations, to obtain ... pathogens ... required for a complete biological control approach to specific pest problems.

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Lymantria dispar — Gypsy Moth

2. Candidate biocontrol agents (when known and appropriate)

   Entomophaga aulicae (fungus) B.t. NPV, parasite complex existing in N. America, also nematode

3. Commodities

   Forest and Shade Trees

4. Status of biocontrol research effort:

   a. Past: An NP virus has been registered by U.S. Forest Service but has not reached a truly commercial status. B.t. is effective but considered rather expensive. 10 parasites and 1 predator are established in U.S.

   b. Present: The pathogen _E. aulicae_ is well documented in the Japanese literature as causing collapse of the gypsy moth in that country. An effort was made in 1907-08 to introduce this pathogen in the U.S. Although the fungus was not cultured nor a successful introduction made, the investigators lost their gypsy moth colony to the pathogen. Efforts to establish additional species of natural enemies in U.S. have been unsuccessful. Cyclic outbreaks still occur with troublesome regularity. NPV is in small scale field trials.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Although gypsy moth has been researched in the United States for many decades, _E. aulicae_ has never been detected. Since gypsy moth was brought into this country without this pathogen, it may be possible to use the "introduction" approach. If not, technology exists which might be adapted to produce a "mycoinsecticide" for this fungus. Ongoing research to improve persistence and activity for NPV as well as other pathogens. Investigate feasibility of a CPY.

6. ARS laboratories involved (present)

   Insect Pathology Research Unit
   Boyce Thompson Institute
   Cornell University
   Ithaca, NY 14853

   Insect Pathology Laboratory, Beltsville
   ARS/Otis ANGB Mass.

7. Other Federal laboratories involved (present/future)

Center for Biological Control of Northeastern
Forest Insects and Diseases
Northeastern Forest Experiment Station
51 Mill Pond Road
Hamden, CT 06514

USFS, Hampton, Mass.
APHIS, Otis ANGB, Mass.

7a. Foreign cooperating organization (present):

Forestry and Forest Products Research Institute
P.O. Box 16
Tsukuba-Norin-Kenkyu-Danchi
Ibaraki 305
Japan

Canadian Forestry Serv., Sault St. Marie

8. Potential State/University cooperation

Penn. State
U. Georgia, Athens
U. Maryland

9. Suggested ARS contact individual(s) - (Key person)

Dr. Richard S. Soper (fungi)
Dr. Shapiro (virus)

10. Funds required

$50,000 (fungi) (June 1, 1984 - August 30, 1985)
$150,000 (virus)

11. SY input needed

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.9a.5: Expand foreign exploration and research, including cooperative research with foreign scientists and organizations, to obtain ... pathogens ... required for a complete biological control approach to specific pest problems.

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   <u>Pyrrhalta luteola</u> — Elm leaf beetle

2. Candidate biocontrol agents (when known and appropriate)

   parasites <u>Eryneriopis antennata</u>, <u>Tetrastichus brevistigma</u>, <u>T. galerucae</u>

3. Commodities

   Elms

4. Status of biocontrol research effort:

   a. Past: Natural enemies established in various regions attacking various stages of insect development.

   b. Present: Recovery of established natural enemies

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Get multiple parasites established in various locations. Availability of exploration natural enemies on Asiatic elms.

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   Michigan St., U. California

9. Suggested ARS contact individual(s) - (Key person)

   John W. Neal

10. Funds required

    $1000,000

11. SY input needed

    1 SY split between different positions

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Pseudaulacaspis pentagona — white peach scale

2. Candidate biocontrol agents (when known and appropriate)

3. Commodities

   peach persimmon various ornamentals

4. Status of biocontrol research effort:

   a. Past: Accidental introduction of natural enemies

   b. Present: Planned research at Beneficial Insect Introduction Laboratory, Beltsville

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Exploration and importation of natural enemies in East Asia

6. ARS laboratories involved (present)

   BIIL - Beltsville; APL for exploration

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

   U. Florida, Monticello; U. Georgia

9. Suggested ARS contact individual(s) - (Key person)

   J. J. Drea, BIIL

10. Funds required

    $100,000/SY

11. SY input needed

    2 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

<u>Otiorhynchus sulcatus</u> — Black vine weevil

2. Candidate biocontrol agents (when known and appropriate)

<u>Beauvaria bassiaena</u>

3. Commodities

Rhododendron, other nursery stock

4. Status of biocontrol research effort:

 a. Past: Screening program at EPL for fungi

 b. Present: Industrial commercialization of fungus

5. Recommended research approaches (augmentation, introduction, pathology, other).

Search in Europe for parasitoids effective against this weevil. Develop mycoinsecticide.

6. ARS laboratories involved (present)

J. W. Neal

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

Mycogen

9. Suggested ARS contact individual(s) - (Key person)

J. W. Neal

10. Funds required

$100,000/SY

11. SY input needed

2 - 1 for pathogens, 1 for explorations

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Thyridopreryz ephemeraformis — Bagworm

2. Candidate biocontrol agents (when known and appropriate)

B.t., N.P.V. Ichnemidde parasites

3. Commodities

ornamental shrubs *Arbor vitiae*

4. Status of biocontrol research effort:

   a. Past: N.P.V. from whattle bag worm was effective in lab and field tests

   b. Present: Screen Ichnomonidae parasites from Japan

5. Recommended research approaches (augmentation, introduction, pathology, other).

Exploration for parasites from Malaysia and South Africa. Locate effective virus and start studies on effectiveness.

6. ARS laboratories involved (present)

None

7. Other Federal laboratories involved (present/future)

8. Potential State/University cooperation

BIRL - N.J.

9. Suggested ARS contact individual(s) - (Key person)

John W. Neal

10. Funds required

$100,000

11. SY input needed

1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

   Fenusa pusilla | Birch leafminer

2. Candidate biocontrol agents (when known and appropriate)

   Lathrolestes nigricollis, *Grypocentrus albipes*, *Phanomeris* sp., *Chrysocharis nitetis*

3. Commodities

   White-barked birches

4. Status of biocontrol research effort:

   a. Past: Parasite complex studied in Europe by Eichoru & Pschorn-Walker

   b. Present: Four species of parasites imported from Europe. Two species (*L. nigricollis* and *C. nitetis*) established.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Introduction of *G. albipes* & *Phanomeris* sp. Evaluation of species released.

6. ARS laboratories involved (present)

   Beneficial Insects Research Laboratory (BIRL)

7. Other Federal laboratories involved (present/future)

   European Parasite Laboratory (EPL) CIBC

8. Potential State/University cooperation

   Pa Bur For

9. Suggested ARS contact individual(s) - (Key person)

   Roger W. Fuester

10. Funds required

    $200,000

11. SY input needed

    0.5 SY x 4 Yrs. = 2.0 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism | Common name

<u>Choristoneuna occidentalis</u> — Western spruce budworm

2. Candidate biocontrol agents (when known and appropriate)

B.t., NPB, fungus <u>Erynra radicans</u> parasites: <u>Glypta fumiferonae</u>; <u>Phytodietus fumiferance</u>, <u>Apanteles fumiferanace</u> and <u>Ceromasia auricaudata</u>

3. Commodities

Douglas-fir, true firs, spruce

4. Status of biocontrol research effort:

a. Past: Limited research

b. Present: Not enough research. Full tree caging for ant parasites.

5. Recommended research approaches (augmentation, introduction, pathology, other).

Explore use of NPV, and other pathogens silviculture augmentation of natural enemies. Introduction of closely related Choristoneura.

6. ARS laboratories involved (present)

None unknown

7. Other Federal laboratories involved (present/future)

Forest Service, Pacific Northwest Expt. Sta, Pacific Southwest Expt. Sta.

8. Potential State/University cooperation

Canadian Forestry Service

9. Suggested ARS contact individual(s) - (Key person)

None

10. Funds required

$30,000 foreign exploration; $50,000/pathogen up to stage of field testing

11. SY input needed

1 per project parasties, pathogens

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Choristoneura fumifernana — Eastern spruce budworm

2. Candidate biocontrol agents (when known and appropriate)

   B.t, NPV, _Erynia radicans_

3. Commodities

   Spruce, fir

4. Status of biocontrol research effort:

   a. Past: B.t. has been very successful. Extensive testing NPV and entomopovirus _Erynra iradicans_ needs strain selection for low temperature variant.

   b. Present: Forest Service look at forest management practices to enhance natural enemies.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Augmentation with silvicultural practices. Importation of new species for control. Need alternate host to produce virus.

6. ARS laboratories involved (present)

   Insect Pathology Research Unit, Ithaca

7. Other Federal laboratories involved (present/future)

   U.S. Forest Service, Hampton Northeastern Forest Expt. Sta.

8. Potential State/University cooperation

   U. Maine, Dept. Entomology

9. Suggested ARS contact individual(s) - (Key person)

   R. Soper

10. Funds required

    $30,000 to select for fungal strains for cold tolerance.
    $30,000 for foreign exploration and importation

11. SY input needed

    1 on each project

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    ?.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Fiorinia externa ferris — elongate hemlock scale

2. Candidate biocontrol agents (when known and appropriate)

   none known

3. Commodities

   Hemlock

4. Status of biocontrol research effort:

   a. Past: None known

   b. Present: Exploration of China for parasites

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Classical importation, introduction

6. ARS laboratories involved (present)

   Asian Parasite Laboratory

7. Other Federal laboratories involved (present/future)

   Beneficial Insects Research Laboratory, Newark, Delaware

8. Potential State/University cooperation

   Conn. Agriculture Expt. Sta., N.J. Dept. Agriculture, Trenton, N.J.

9. Suggested ARS contact individual(s) - (Key person)

   R. W. Fuester

10. Funds required

    $120,000/yr.

11. SY input needed

    1 overseas; 1 national; two positions 3 yr. project

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Matsococcus resinosae — Red pine scale

2. Candidate biocontrol agents (when known and appropriate)

   Harmonia sp. (beetles from China)

3. Commodities

   red pine

4. Status of biocontrol research effort:

   a. Past: Little more than species description.

   b. Present: Attempt to use Harmonia sp.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Foreign exploration

6. ARS laboratories involved (present)

   Beneficial Insects Research Laboratory, Newark, N.J.
   Asian Parasite Laboratory

7. Other Federal laboratories involved (present/future)

   None

8. Potential State/University cooperation

   Conn. Agriclt. Sta., N.J. Dept. of Agriculture, N.Y. State Dept. Environmental Res.

9. Suggested ARS contact individual(s) - (Key person)

   Paul W. Schaefer

10. Funds required

    $120,000/SY

11. SY input needed

    .5 over 4 years.

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   <u>Alsophila</u> <u>pometaria</u> — fall canker worm

2. Candidate biocontrol agents (when known and appropriate)

   Hymenopterous parasites

3. Commodities

   various hardwoods

4. Status of biocontrol research effort:

   a. Past: Use of <u>A.</u> <u>californica</u> in host range studies

   b. Present: No present ongoing research

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Basic research on parasite complex, foreign exploration in Europe. It is apparently suseptable to <u>A.</u> <u>californica</u> NPV which may be pursued.

6. ARS laboratories involved (present)

   None.

7. Other Federal laboratories involved (present/future)

   No funding available.

8. Potential State/University cooperation

   N.J. Dept. Agriculture

9. Suggested ARS contact individual(s) - (Key person)

   R. W. Fuester (future)

10. Funds required

    $120,000/yr.

11. SY input needed

    1-2 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Paleacrita vernata — spring cankerworm

2. Candidate biocontrol agents (when known and appropriate)

   hymenopterous parasites

3. Commodities

   Hardwoods

4. Status of biocontrol research effort:

   a. Past: None

   b. Present: None

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Basic research on parasite complex, foreign exploration in Europe.

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   No funding available.

8. Potential State/University cooperation

   N.J. Dept. Agriculture

9. Suggested ARS contact individual(s) - (Key person)

   R. W. Fuester

10. Funds required

    $120,000/yr.

11. SY input needed

    1-2

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   Malacosama disstria — forest tent caterpillar

2. Candidate biocontrol agents (when known and appropriate)

   virus-fungus complex, wide host range

3. Commodities

   oaks, sugar maple, aspen, poplars, birch, sweet gum, black gum, water tupelo

4. Status of biocontrol research effort:

   a. Past: Identification of parasite complex, some work with microsporida identification of several pathogens including NPV, CPU and fungus Eryana crustosa

   b. Present: Demonstration of microsporidian persistance.

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Research on pathogens, NPV and fungus exploration in Europe for natural enemies on Malacosoma neustria

6. ARS laboratories involved (present)

   None

7. Other Federal laboratories involved (present/future)

   Ithaca, NY; ANGB, MA

8. Potential State/University cooperation

   Witter Kulman, U. Minn.

9. Suggested ARS contact individual(s) - (Key person)

   R. W. Fuester

10. Funds required

    $100,000 parasites, $50,000 fungus, $25,000 virus

11. SY input needed

    2 SY x 3 years parasites .5 fungus

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

Reticulitermes spp. — termites

2. Candidate biocontrol agents (when known and appropriate)

nematodes (aarduarks) fungus *Metarhizium anisoplae*

3. Commodities

wood in use and storage

4. Status of biocontrol research effort:

a. Past: Control of gut protozoa

b. Present: Control of gut protozoa, use of nematodes

5. Recommended research approaches (augmentation, introduction, pathology, other).

Determine why certain woods are resistant to termite infestation. Research on gut flora of termite. Further exploration of control by nematodes. Development of mycoinsecticide. Explorations in Africa.

6. ARS laboratories involved (present)

Fort Lauderdale, FL

7. Other Federal laboratories involved (present/future)

Southern Gulf Port Expt. Sta.

8. Potential State/University cooperation

U. Hawaii, Boyce Thompson Inst.

9. Suggested ARS contact individual(s) - (Key person)

Soper (fungus)

10. Funds required

$120,000/SY

11. SY input needed

1 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

2.4.9a.5

Information Summary for Target Pest for ARS Biological Control Program

1. Pest organism — Common name

   <u>Orgyia pseudotsugata</u> — Douglas-fir tussock moth

2. Candidate biocontrol agents (when known and appropriate)

   B.t., N.P.V., Imports of <u>Orgyia</u> species in the Old World

3. Commodities

   Douglas Fir

4. Status of biocontrol research effort:

   a. Past: Attempted to use gypsy moth control for tussock moth. Good results with N.P.V.

   b. Present: Historical research on population dynamics. Demonstrated moth is suseptible to <u>A. californica</u> NPV

5. Recommended research approaches (augmentation, introduction, pathology, other).

   Solve problems inherent in production of virus in alternate host. Develop cheaper virus production. Search for parasite of <u>Orgyia</u> in Europe.

6. ARS laboratories involved (present)

   Otis AFGB, Mass.

7. Other Federal laboratories involved (present/future)

   La Grande, Pacific Northwest Exp. Sta.

8. Potential State/University cooperation

   Oregon State, Sault Ste. Marie

9. Suggested ARS contact individual(s) - (Key person)

   Dr. Shapiro

10. Funds required

    $1000,000

11. SY input needed

    2-3 SY

12. Appropriate Approach element(s) and problem(s) and subproblem(s)

    2.4.9a.5

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